

Behaviour of elements from lithium to europium in stars with and without planets ^{*}

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ABSTRACT

We conducted an analysis of the distribution of elements from lithium to europium in 200 dwarfs in the solar neighbourhood (~ 20 pc) with temperatures in the range 4800–6200 K and metallicities $[\text{Fe}/\text{H}]$ higher than -0.5 dex. Determinations of atmospheric parameters and the chemical composition of the dwarfs were taken from our previous studies. We found that the lithium abundances in the planet-hosting solar-analog stars of our sample were lower than those in the stars without planetary systems. Our results reveal no significant differences exceeding the determination errors for the abundances of investigated elements, except for aluminium and barium, which are more and less abundant in the planet-hosting stars, respectively. We did not find confident dependences of the lithium, aluminium and barium abundances on the ages of our target stars (which is probable because of the small number of stars). Furthermore, we found no correlation between the abundance differences in $[\text{El}/\text{Fe}]$ and the condensation temperature (T_{cond}) for stars in the 16 Cyg binary system, unlike the case for 51 Peg (HD 217014), for which a slight excess of volatile elements and a deficit of refractories were obtained relative to those of solar twins. We found that one of the components of 16 Cyg exhibits a slightly higher average abundance than its counterpart ($\langle [\text{El}/\text{H}](\text{A}-\text{B}) \rangle = 0.08 \pm 0.02$ dex); however, no significant abundance trend versus T_{cond} was observed. Owing to the relatively large errors, we cannot provide further constraints for this system.

Key words: stars: abundances – planetary systems.

1 INTRODUCTION

A large number of studies of planet-hosting stars (Gonzalez 1997, 1998; Santos, Israelian & Mayor 2000; Fischer & Valenti 2005; Udry & Santos 2007; Adibekyan et al. 2012a,b, etc) have been carried out over recent decades with the aim of increasing our understanding of the processes involved in the formation of planets. The earliest studies of the metallicity of planet-hosting stars (e.g. Gonzalez 1997), as well as subsequent ones (see Udry & Santos 2007, and reference therein) indicated that most of these stars are rich in metals. There are two possible explanations for the excess metallicity observed. The first is the infall of metal-rich (planetary) material into the stellar envelope (e.g. Gonzalez 1998) and the second is

related to the prestellar enrichment of interstellar matter (Fischer & Valenti 2005, and references therein). The issue has not yet been finally resolved; however, the second assumption is to be preferred, as the infall of matter cannot provide an appreciable increase in the metal abundance.

The high metallicity of planet-hosting stars is well-established for stars with massive planets (Jupiter-like ones) (Gonzalez 1997; Santos, Israelian & Mayor 2000, 2001; Fischer & Valenti 2005; Sousa et al. 2008), while it is not for stars with less massive planets, namely those with planets the size of Neptune or Earth (e.g. Udry & Santos 2007; Sousa et al. 2008, 2011; Wang & Fischer 2015). The results of Buchhave et al. (2012) suggest that terrestrial planets have no special requirement for enhanced metallicity for their formation, and they support the hypothesis that stars hosting terrestrial planets have a metallicity similar to stars with no known transiting planets (Buchhave & Latham

^{*} Tables A1-A3 are only available in electronic form

2015). Sousa et al. (2008) and (Adibekyan et al. 2012a,b) drew attention to the possibility of planet formation for metallicities lower than solar. It was shown that there is an excess of α -elements, especially magnesium, in the stars with low-mass planets, which is more pronounced in the thick-disc population than in the thin disc for metallicities below -0.3 dex (Adibekyan et al. 2012a,b). This implies that metals other than iron may noticeably contribute to planetary formation if the iron abundance is low.

Lithium plays a unique role in the study of planet-hosting stars. Its abundance is apparently lower in the stars with planetary systems than in those without (Gonzalez & Laws 2000; Gonzalez 2008; Gonzalez, Carlson & Tobin 2010; Israelian et al. 2004, 2009; Delgado Mena et al. 2014; Figueira et al. 2014; Delgado Mena et al. 2015). In particular, Delgado Mena et al. (2014) found that there is some evidence that lithium depletion in planet-hosting solar-type stars is higher when their planets are more massive than Jupiter. Hot stars that host Jupiter-like planets and have effective temperature T_{eff} in the range of 5900–6300 K show lithium abundances that are 0.14 dex lower than those in stars without detected planets (Delgado Mena et al. 2015). It should be noted, however, that lithium depletion is usually associated with stellar evolution (Denissenkov 2010; Talon & Charbonnel 2005; Andr  ssy & Spruit 2015), a phenomenon that is confirmed by the dependence of lithium abundances on age (e.g. Monroe et al. 2013; Mel  ndez et al. 2014; Carlos, Nissen & Mel  ndez 2016). Carlos, Nissen & Mel  ndez (2016) found that the lithium abundances of solar twin stars are a function of stellar age, while there is no indication of any relationship between planet-hosting stars and enhanced lithium depletion.

In order to identify either the presence or the absence of a possible relation between chemical abundances and mechanisms of planetary formation, various studies have been performed to examine the chemical peculiarities of planet-hosting stars (e.g. Mel  ndez et al. 2009; Ram  rez, Mel  ndez & Asplund 2009; Adibekyan et al. 2015b), the main properties of planets and their hosts (e.g. mass) (Kang, Lee & Kim 2011; Dorn et al. 2015; Sousa et al. 2015), their position in the Galaxy (Haywood 2008, 2009; Adibekyan et al. 2014), and Galactic evolution (e.g. Adibekyan et al. 2015b). Studies of the chemical composition of the Sun, solar twins and solar analogues that have highly accurate abundance determinations (~ 0.01 dex), Mel  ndez et al. (2009) shown a decrease in the relative content of refractory elements in the Sun, namely one that is by 20% lower than those of solar-analogue stars and solar twins with giant planets. Because a correlation between the abundance differences and condensation temperature T_{cond} was found, these authors speculated that the decrease in the relative content was associated with the presence of Earth-like planets. In the literature, there are several alternative explanations for the abundance trends with T_{cond} . Adibekyan et al. (2014) found that chemical peculiarities (i.e. small refractory-to-volatile ratio) of planet-hosting stars are likely to reflect their older age and inner Galactic origin; hence, stellar age and, probably, Galactic origin are the key factors to establish the abundances of some specific elements. It has also been suggested that the T_{cond} trend correlates strongly with stellar radius

and mass (Maldonado et al. 2015; Maldonado & Villaver 2016). The trend may also depend on stellar environment (  nehag, Gustafsson & Korn 2014), and internal processes, such as gas-dust segregation in the protostellar disc (Gaidos 2015). Recently, Adibekyan et al. (2016) found that the T_{cond} trend may depend strongly on the spectra of the stars used. In particular, these authors observed significant differences in the abundances of the same star as derived from different high-quality spectra. Previously, Sousa et al. (2008) had suggested that the detectability of Neptune-class planets may increase in stars with a low metallicity. Kang, Lee & Kim (2011) also confirmed the presence of chemical abundance differences between stars with and without exoplanets, as well as the relationship between chemical abundances and planetary mass. Sousa et al. (2015) studied the effect of stellar mass on the derived planetary mass and noted that the stellar mass estimates for giant stars should be employed with extreme caution when computing planetary masses.

Binary systems of stellar twins are important objects in this investigation, as the effects of stellar age (chemical evolution) or birthplace in the Galaxy are similar for both components of the binary pair. Nissen (2015) showed that there are clear correlations between [El/Fe] ratios and stellar ages in solar twins. Teske, Khanal & Ram  rez (2016) found that both components in the binary system WASP 94 A and B are planet-hosting stars, and they differ in their chemical composition. The binary system HD 80606/HD80607 exhibits no remarkable differences in the abundances of its components, despite the fact that the star HD 80606 hosts a giant planet (Saffe, Flores & Buccino 2015; Mack et al. 2016). However, abundance variations were found in the XO-2 planet-hosting binary from independent observations (Biazzo et al. 2015; Ram  rez et al. 2015; Teske et al. 2015). As reported by Spina, Mel  ndez & Ram  rez (2016) the abundance ratios [El/Fe] show signatures of both chemical evolution and planets.

Our group has investigated nearly 600 stars, dwarfs and giants over several years. We determined their atmospheric parameters and chemical composition in order to study the chemical and dynamical evolution of the Galaxy and, primarily, the chemical enrichment of various Galactic substructures (Mishenina et al. 2004, 2006, 2008, 2012, 2013, 2015a,b). We detected 14 planet-hosting stars among the target ones. It would be interesting to examine the behaviour of the abundances of various elements, including lithium, refractory and volatile elements, as well as neutron-capture elements for the stars with and without planets that are present in our data base. Such a study could enable an independent analysis of the correlation between the presence of planets and the chemical composition of stars, possibly shedding some light on the existing contradictions, as well as re-examining earlier determined constraints on the mechanisms of formation of planets and planetary systems.

The paper is set out as follows. The observations and selection of stars, as well as determination of stellar parameters and elemental abundance are described in §2. The analysis of element abundances is presented in §3. In §4, the correlations between elemental abundances and condensation temperatures are discussed. The connection with chemical enrichment of galactic disc is reported in §5. 6 summarizes and concludes the paper.

2 OBSERVATIONS AND DETERMINATION OF PARAMETERS AND CHEMICAL COMPOSITION

Our sample consists of 200 dwarfs with temperatures in the range 4800 – 6200 K and metallicities from -0.4 dex that correspond to the range of stellar parameters of 14 stars that host planets (Exoplanets.eu database; Schneider et al. (2011)) from our data base. Table 1 lists the main characteristics of the planet-hosting stars and planets (with their masses in units of the mass of Jupiter (M_J)).

Here, we make a few comments regarding the observational data and the techniques for determining the parameters and chemical composition. It is important that all our determinations of both parameters and chemical composition are performed using uniform methods. The spectra of investigated stars (F-G-K dwarfs) were obtained in the region of λ 4400–6800 Å with typical signal-to-noise ratios S/N of about 100–350 using the 1.93 m telescope at Observatoire de Haute-Provence (OHP, France) equipped with the echelle-spectrograph ELODIE (Baranne et al. 1996), which gives a resolving power of $R = 42000$. The initial processing of the spectra (order extraction, flat-fielding, wavelength calibration and radial velocity determination) was performed with the standard online ELODIE reduction software, while the order deblazing and the cosmic, telluric lines and bad pixel removing were performed following the recipes described in Katz et al. (1998). Further treatment of spectra (the continuous spectrum level placement, measurement of the equivalent widths etc.) was conducted using the DECH20 software package (Galazutdinov 1992).

The atmospheric parameters of the target stars were determined in our previous works. The methods and techniques applied are described in detail in Mishenina et al. (2004) and Mishenina et al. (2008). The effective temperatures T_{eff} were estimated by the calibration of the ratio of the central depths of lines with different potentials of the lower level developed by Kovtyukh et al. (2003), with typical internal errors better than 10 K. The surface gravities, $\log g$ for the stars with T_{eff} higher than 5000 K were computed using two methods, namely the iron ionization balance and the parallax. For stars with T_{eff} lower than 5000 K, we used only the trigonometric parallax method. The microturbulence velocity V_t was derived providing that the iron abundance $\log A(\text{Fe})$ obtained from Fe I lines was not correlated with the equivalent width, EW. The adopted metallicity value $[\text{Fe}/\text{H}]$ was the iron abundance obtained from the Fe I lines under the local thermodynamic equilibrium (LTE) approximation. We note that the non-LTE corrections for the range of temperatures and metallicities of our target stars do not exceed 0.1 dex (Mashonkina et al. 2011). In our previous papers, the external errors were estimated to be of the order 100 K in T_{eff} , 0.2 dex in $\log g$ and 0.1 in $[\text{Fe}/\text{H}]$. However, extensive comparisons with other studies that have a significant number of the investigated stars in common suggest that our atmospheric parameters were more accurate than expected. The results of these comparisons are shown in Table 2, which lists the mean differences and standard deviations. The mean differences reflect the biases resulting from the application of different techniques, atomic data and spectroscopic observations. They do not exceed 33 K in T_{eff} , 0.15 in $\log g$ and 0.05 in $[\text{Fe}/\text{H}]$, which

is indicative of the fact that our data are in good agreement with those reported in other studies. The standard deviations define an upper limit for our external errors provided that the other studies have their own (unknown) uncertainties. Standard deviations range from 33 to 89 K in T_{eff} from 0.11 to 0.21 in $\log g$ and from 0.05 to 0.09 in $[\text{Fe}/\text{H}]$. We expect our typical errors for a range of parameters to lie between these values; hence, we adopt conservative estimates of $\delta T_{\text{eff}} = \pm 60$ K, $\delta \log g = \pm 0.16$ dex and $\delta [\text{Fe}/\text{H}] = 0.06$ dex for the accuracy of our atmospheric parameters.

The abundances of most investigated elements were obtained under the LTE approximation using the atmosphere models by Kurucz (1993), the EWs of lines, and the WIDTH9 code by Kurucz (Mishenina et al. 2004, 2008, 2012, 2013, 2015a). The Li, O, S, Mn, and Eu abundances were determined from the synthetic spectra calculated by a new version of the STARS LTE spectral synthesis code (Tsymbal 1996) with hyperfine structure factored in for the abundances of S, Mn, and Eu. The Na, Al, Mg, and Ba abundances were estimated under the non-LTE approximation using the MULTI code (Carlsson 1986) modified by S.A. Korotin (Korotin, Andrievsky & Luck 1999). The abundance of the investigated elements were determined by differential analysis relative to the Sun. The solar abundances were calculated using the Moon and asteroid spectra, which had also been obtained with the ELODIE spectrograph, and with the same atomic parameters as for the stars, both for the EW and spectral synthesis analysis. The differential analysis was performed for Na, Al, Mg, Mn, and Ba on a line-by-line basis, while for other elements averaged chemical abundances were used.

The results of the comparison of our parameters for the target stars and for the planet-hosting stars with the data of other authors (Luck & Heiter 2006; Fuhrmann 2008; Gonzalez, Carlson & Tobin 2010; da Silva, Milone & Reddy 2011; Casagrande et al. 2011; Maldonado et al. 2012; Ramírez, Allende Prieto & Lambert 2013; da Silva, Milone & Rocha-Pinto 2015; Santos et al. 2013; Kang, Lee & Kim 2011) are presented in Tables 2 and A1. There is a good agreement with our external comparison.

In our previous works, we analysed the errors in the abundance determinations that resulted from the choice of the atmospheric model parameters and EW measurements (Gaussian fitting, placement of the continuum) or from the synthetic spectrum fitting. For instance, for the n-capture element abundances (Mishenina et al. 2013), we found that the total uncertainty reaches 0.14–0.15 dex for the stars with low temperatures, and 0.08–0.13 dex for the hotter stars. However, this was done assuming larger parameter errors than estimated here. Adopting errors of $\delta T_{\text{eff}} = \pm 60$ K, $\delta \log g = 0.16$ dex and $\delta [\text{Fe}/\text{H}] = 0.06$ dex, we obtain new values of determination errors (See Tables 3 and 4). In this case, the determination accuracy varies from 0.03 to 0.12 dex for all elements.

Tables A2, A3, detailing atmospheric parameters and elemental abundances in the studied stars, are available online (see Appendix).

Table 1. Characteristics of the planet-hosting stars and planets. Atmospheric parameters are from our previous papers (Mishenina et al. 2004, 2008, 2012) while the masses of the planets are from the Exoplanets.eu data base (Schneider et al. 2011).

HD	T_{eff} (K)	$\log g$	[Fe/H]	Planet	Mass (M_J)
3651	5277 ± 5	4.5 ± 0.20	0.15 ± 0.10	HD 3651 b	0.2
7924	5165 ± 5	4.4 ± 0.20	-0.22 ± 0.10	HD 7924 d	0.0203
				HD 7924 c	0.0247
				HD 7924 b	0.0273
9826	6074 ± 10	4.0 ± 0.20	0.10 ± 0.10	ups And c	1.8
				ups And d	10.19
				ups And b	0.62
38858	5776 ± 5	4.3 ± 0.20	-0.23 ± 0.10	HD 38858 b	0.0961
87883	5015 ± 5	4.4 ± 0.20	0.00 ± 0.10	HD 87883 b	12.1
95128	5887 ± 4	4.3 ± 0.20	0.01 ± 0.10	47 Uma d	1.64
				47 Uma c	0.54
97658	5136 ± 8	4.5 ± 0.20	-0.32 ± 0.10	HD 97658 b	0.02375
128311	4960 ± 4	4.4 ± 0.20	0.03 ± 0.10	HD 128311 c	3.21
145675	5406 ± 9	4.5 ± 0.20	0.32 ± 0.10	14 Her b	4.64
154345	5503 ± 6	4.3 ± 0.20	-0.21 ± 0.10	HD 154345 b	1.0
156668	4850 ± 5	4.2 ± 0.20	-0.07 ± 0.10	HD 156668 b	0.0131
186427	5752 ± 4	4.2 ± 0.20	0.02 ± 0.10	16 Cyg B b	1.68
189733	5818 ± 5	4.3 ± 0.20	-0.03 ± 0.10	HD 189733 b	1.138
217014	5778 ± 4	4.2 ± 0.20	0.14 ± 0.10	51 Peg b	0.46

Table 2. Comparison of our parameter determinations for all our stars and planet-hosting stars with the results by other authors for the n common stars.

References	$\Delta(T_{\text{eff}}, \text{K})$	$\Delta(\log g)$	$\Delta([\text{Fe}/\text{H}])$	n
<i>all our stars:</i>				
Luck & Heiter (2006)	33 ± 81	0.13 ± 0.21	0.04 ± 0.09	49
Fuhrmann (2008)	-25 ± 33	0.08 ± 0.17	0.01 ± 0.06	32
Gonzalez et al. (2010)	-12 ± 80	0.00 ± 0.11	0.05 ± 0.06	31
Da Silva et al. (2011)	-25 ± 83	0.03 ± 0.19	0.00 ± 0.05	41
Casagrande et al. (2011)	-3 ± 82	–	–	160
Maldonado et al. (2012)	-26 ± 89	0.15 ± 0.18	0.03 ± 0.08	54
Ramirez et al. (2013)	-14 ± 47	0.10 ± 0.13	0.01 ± 0.06	51
Da Silva et al. (2015)	-12 ± 79	0.04 ± 0.16	0.03 ± 0.05	74
<i>planet host stars:</i>				
Maldonado et al. (2012)	61 ± 55	-0.05 ± 0.12	-0.03 ± 0.07	11
Ramirez et al. (2012)	18 ± 34	-0.02 ± 0.12	0.00 ± 0.06	5
Santos et al. (2013)	27 ± 65	-0.09 ± 0.15	-0.03 ± 0.05	14
Kang et al. (2011)	-32 ± 39	-0.18 ± 0.08	-0.05 ± 0.05	8

Table 3. Influence of the stellar parameters on the abundance determinations for an example star, HD 7924 ($T_{\text{eff}}=5165$ K, $\log g=4.4$, $Vt=1.1$ km/s, $[\text{Fe}/\text{H}] = -0.22$).

Species	$\Delta T_{\text{eff}} + 60 \text{ K}$	$\Delta \log g + 0.16$	$\Delta Vt + 0.2 \text{ km/s}$	Total
O I	0.01	0.06	0.01	0.06
Na I	0.04	0.02	0.00	0.04
Mg I	0.04	0.01	0.02	0.05
Al I	0.04	0.01	0.02	0.05
Si I	0.01	0.01	0.03	0.03
S I	0.01	0.01	0.03	0.03
Ca I	0.05	0.02	0.07	0.09
Mn I	0.01	0.05	0.07	0.09
Fe I	0.05	0.01	0.04	0.06
Fe II	0.05	0.05	0.04	0.08
Ni I	0.03	0.02	0.03	0.05
Zn I	0.02	0.03	0.03	0.06
Y II	0.02	0.04	0.08	0.09
Zr II	0.00	0.06	0.02	0.06
Ba II	0.02	0.03	0.11	0.12
La II	0.02	0.06	0.04	0.07
Ce II	0.01	0.05	0.00	0.05
Nd II	0.00	0.04	0.03	0.05
Eu II	0.01	0.05	0.02	0.05

3 ANALYSIS OF ELEMENTAL ABUNDANCE BEHAVIOUR IN STARS WITH AND WITHOUT PLANETS

In Fig. 1 we present the distribution of stars with and without planets on the $[\text{Fe}/\text{H}]$ versus T_{eff} plane. As can be seen from Table 1 and from Fig. 1, the temperatures of some stars with detected planets are lower than those of the solar twins selected in this paper. In addition, it can also be seen that several planet-hosting stars have slightly deficient metallicities. This confirms the possibility of the planetary formation around stars with low metallicity, as suggested by

Table 4. Influence of the stellar parameters on the abundance determinations for an example star, HD 95128 ($T_{\text{eff}}=5887$ K, $\log g=4.3$, $Vt=1.1$ km/s, $[\text{Fe}/\text{H}] = 0.01$).

Species	$\Delta T_{\text{eff}}+60$ K	$\Delta \log g+0.16$	$\Delta Vt+0.2\text{km/s}$	Total
O I	0.01	0.05	0.01	0.05
Na I	0.04	0.02	0.00	0.04
Mg I	0.04	0.01	0.03	0.05
Al I	0.03	0.02	0.03	0.05
Si I	0.01	0.01	0.03	0.03
S I	0.01	0.01	0.03	0.03
Ca I	0.04	0.02	0.06	0.07
Mn I	0.01	0.05	0.07	0.09
Fe I	0.03	0.01	0.04	0.05
Fe II	0.04	0.04	0.03	0.06
Ni I	0.04	0.02	0.03	0.05
Zn I	0.02	0.03	0.03	0.06
Y II	0.02	0.04	0.08	0.09
Zr II	0.01	0.06	0.02	0.06
Ba II	0.03	0.04	0.12	0.13
La II	0.03	0.06	0.04	0.08
Ce II	0.02	0.04	0.01	0.05
Nd II	0.02	0.05	0.04	0.07
Eu II	0.03	0.05	0.01	0.06

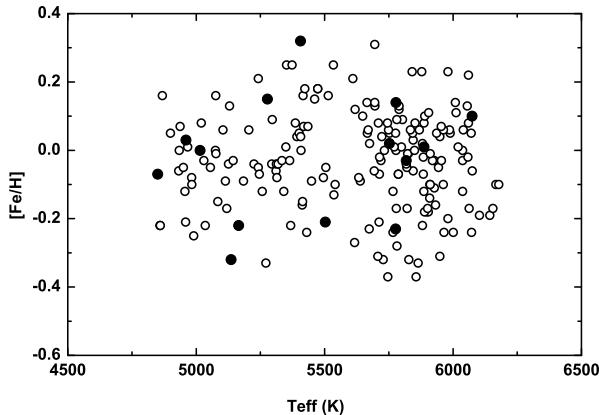


Figure 1. Dependence of $[\text{Fe}/\text{H}]$ on T_{eff} for our studied stars. Stars without detected planets are marked as open circles; those with planets as filled circles.

Adibekyan et al. (2012b) and Buchhave & Latham (2015), among others.

A number of authors have highlighted the dependence of the mass of the planet on the stellar metallicity (e.g. Sousa et al. 2008; Kang, Lee & Kim 2011). The dependence of the mass of the planet (in units of Jupiter mass, M_J) is shown in Fig. 2. We observe a negligible trend of planetary masses with metallicity. In fact, the two stars with the most massive planets (with masses of about $12 M_J$) have a solar metallicity. Therefore, our small sample does not enable us to affirm the presence of a real trend; rather, it is more likely that one does not exist. The absence of a strong trend agrees with the results of Adibekyan et al. (2013), who found no significant correlation between planetary mass and the metallicity of host stars with Jupiter-like planets.

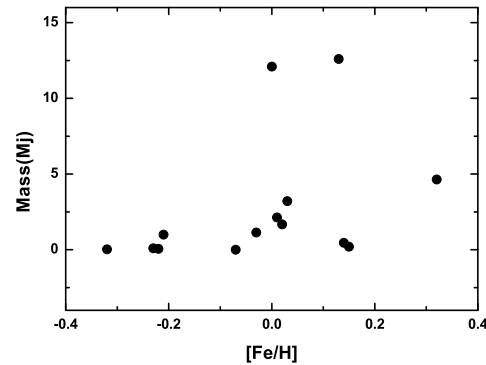


Figure 2. Dependence of the planetary mass (in M_J) on $[\text{Fe}/\text{H}]$ for our planet-hosting stars.

3.1 Lithium

Lithium was the first element whose underabundance was associated with the presence of planets, as reported in many studies (e.g. Gonzalez & Laws 2000; Gonzalez 2008; Gonzalez, Carlson & Tobin 2010; Israelian et al. 2004, 2009; Delgado Mena et al. 2014; Figueira et al. 2014; Delgado Mena et al. 2015). The behaviour of the lithium abundance is not simple and depends on many parameters. Lithium burns at temperatures of 2.5×10^6 K via α -captures, which makes it a useful tool to study mixing processes in stars. Apart from convective overshooting, there are also other mechanisms that result in changes of the lithium abundance, such as meridional circulation or diffusion. Lithium appears to be the most thoroughly investigated element, a large number of studies have focused on the relationship between the lithium abundance in a star and its properties, such as mass, age, rotation, chromospheric activity, etc. In this paper, we compare the lithium behaviour in planet-hosting and other dwarfs from our group of target stars (Fig. 3).

The lithium abundances were determined by synthetic spectra tools using a new version of the STARS LTE spectral synthesis code (Tsymbal 1996) and the list of lines in the region of the Li I line 6707 \AA from Mishenina & Tsymbal (1997). In this study, the lithium abundances of 84 stars were derived for the first time, while those of the remaining 56 stars were taken from our previous studies (Mishenina et al. 2008, 2012). In spite of the errors in the lithium abundance estimate, arising for various reasons, we emphasize here that the effective temperature is the key parameter, whose accuracy is crucial in the lithium abundance determination. Recently, Figueira et al. (2014) applied multivariable regression to study the role of presence of planets on the lithium abundance in stars. These authors, by simultaneously considering the impact of different parameters on lithium abundances, concluded that planet-hosting stars display a depletion in lithium.

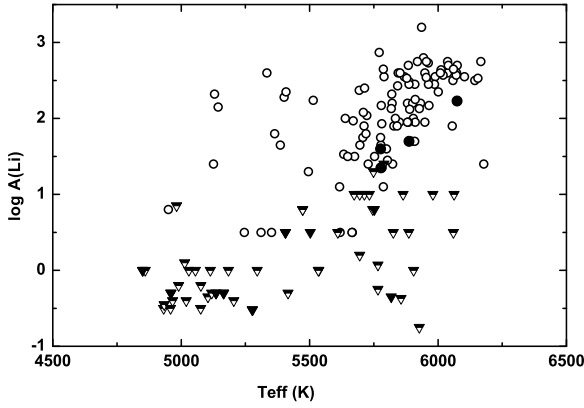
As we can be seen from Table 5, the difference between the values obtained by different authors is within 0.1 dex. We have not determined the lithium abundance for HD 87883 because the spectrum is distorted in the region of the lithium lines.

A comparison of the lithium patterns in stars with and

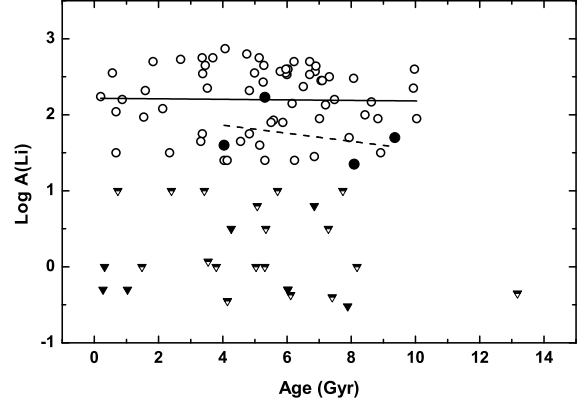
Table 5. Stellar age and lithium abundance in the stars with detected planets.

HD	Li	Li _{up}	4	5	6	Age (Gyr)
3651	–	–0.52	0.39	–	–	7.89:
7924	–	–0.30	–	–	–	1.03:
9826	2.23	–	2.28	–	2.47	5.31
38858	1.60	–	–	1.49	1.64	4.03:
87883	–	–	–	–	–	8.92
95128	1.70	–	1.72	–	–	9.35:
97658	–	–0.30	–	–	–	0.27:
128311	–	–0.30	–	–	<–0.37	6.03
145675	–	0.50	–	–	<–0.02	4.26:
154345	–	0.50	–	–	–	–
156668	–	0.00	–	–	–	0.32:
186427	–	0.80	0.75	–	<0.60	6.85
189733	–	–0.35	–	–	–	–
217014	1.35	–	1.21	1.29	1.30	8.09

Notes: Li– our lithium abundance determination;
 Li_{up} – upper limit of the lithium abundance;
 4 –Ramírez et al. (2012), 5 – Delgado Mena et al. (2015),
 6 – Israelian et al. (2004), 7 – stellar age,
 the values of age marked with (:) correspond to more uncertainties in age determinations.

**Figure 3.** Dependence of log A(Li) on T_{eff} for our studied stars. Designations are as in Fig. 1. The stars with and without planets having an upper limit of Li abundance marked as filled and semi-filled triangles.

without detected planets is presented in Fig. 3. As can be seen from the figure, the lithium abundances of planet-hosting stars are lower than those in the dwarfs without detected planets. In our example, the lithium abundance of planet-hosting stars is not greater than 1.7, with the only exception being HD 9826 ($T_{\text{eff}} = 6074$ K), and for most of these stars we found only the upper limit of lithium abundance (it should be noted that these values depend on the signal-to-noise ratio and resolution of the spectra). There are two possible explanations for our results (i.e. the low lithium abundance). First, we had a small selection of planet-hosting stars, namely 14. Secondly, the temperature of several planet-hosting stars was lower than $T_{\text{eff}} < 5500$ K, the temperature at which convection is the main mechanism for the lithium depletion. However, the lithium abundances in hot planet-hosting stars are lower than in dwarfs with sim-

**Figure 4.** Relation between the lithium abundance log A(Li) and age for our studied stars. Designations are as in Fig. 3.

ilar values of T_{eff} . These results are in good agreement with those obtained in earlier studies (e.g. Israelian et al. 2004). These authors suggested that there is a likely excess lithium depletion in planet-hosting stars with T_{eff} in the range 5600–5850 K, but no significant differences in the stars with T_{eff} in the range 5850–6350 K. In a recent study (Figueira et al. 2014), it was reported that such an offset is negative indicating an enhanced depletion in planet-hosting stars; it was also shown that the results obtained were statistically meaningful. For a larger sample of 326 Main-Sequence stars with and without planets and a T_{eff} range of 5600–5900 K (Delgado Mena et al. 2014), the lithium abundance determinations suggested that the amount of lithium depletion in planet-hosting solar-type stars is higher when the masses of planets exceed $1M_J$. Finally, Delgado Mena et al. (2015) found that the lithium abundances in the stars hosting hot Jupiters with a T_{eff} range of 5900–6300 K is by 0.14 dex lower than in stars without detected planets. In our sample, there are four stars with planetary systems in the temperature range 5700–6100 K with masses greater than $1M_J$. There is only one star, namely HD9826 with $T_{\text{eff}} = 6074$ K and a planetary mass of about $12 M_J$ that exhibits a high lithium abundance of 2.23 dex. A different view of the lithium behaviour has, however, been expressed in a number of papers (e.g. Baumann et al. 2010; Carlos, Nissen & Meléndez 2016, etc). In particular, some authors found strong evidence that lithium depletion increases with age, a finding that is pertinent to stellar evolution rather than to the presence of planets. Fig. 4 shows the dependence of lithium abundance on stellar age for our sample. The age determinations were taken from (Mishenina et al. 2013). The reliable age determinations were made using tracks Mowlavi et al. (2012) and only for the objects fitted by the correct isochrones set with pair-wise Euclidean distances in two-dimensional space (presented by T_{eff}/T_{\odot} and L/L_{\odot}) smaller than 0.02. The age of the stars whose determinations were made with increments smaller than 0.05 are marked with a colon (:) in Table 5.

As we can be seen from Fig. 4, there is no dependence of lithium on the age of the stars with detected lithium abundance. The slope for the stars without planets is -0.003 ± 0.023 and it is -0.053 ± 0.100 for the stars with planets. Unfortunately, we have only four stars with planets and detected lithium abundance. Two of the stars, HD 9826 and

HD 217014, with detected lithium (2.23 and 1.35) have ages 5.31 Gyr and 8.09 Gyr, respectively. For the other two stars, the age determinations are uncertain. Hence, it is not possible to draw any reliable conclusions about the correlation between the lithium abundance and age. As we consider such a small number of stars for which lithium is detected, our results sustain the hypothesis regarding lithium dilution in stars with planets to some extent, while the existence of a correlation between the lithium abundance and age is supported to an even lesser extent.

3.2 α -elements (Mg, Si, Ca)

In Fig. 5 and 6, we present the dependence of the $[\text{El}/\text{Fe}]$ abundance ratios on the stellar metallicity. As can be seen from these figures, there are no significant differences between stars with and without planets. It is likely that we cannot see the same enhancement in α -elements as it was shown in (Adibekyan et al. 2012a,b) owing to the lack of low-metallicity stars in our target sample.

If the mass and radius are known, it is possible to derive constraints on the interior structure of exoplanets (Dorn et al. 2015). Using an inversion method based on Bayesian analysis, these authors investigated constraints on the interior structure of terrestrial exoplanets, in the form of the chemical composition of the mantle and the core size. In particular, they concluded that stellar elemental abundances (Fe, Si, Mg) are the principal constraints for reduction of degeneracy in interior structure models and limiting factors for the mantle composition. Therefore, the study of these elements is essential in order to detect either small-mass rocky planets or rocky cores of massive planets based on the stellar chemical composition. Santos et al. (2015) derived stellar parameters and chemical abundances for Fe, Si, Mg, O, and C in three stars hosting low-mass planets, rocky planets, and suggested that stellar abundances can be used to add constraints on the composition of orbiting rocky planets. For our studied stars, we have derived the dependences of $[\text{Mg}/\text{Si}]$ on $[\text{Fe}/\text{H}]$ and $[\text{Fe}/\text{Si}]$ (see Figs. 7, 8). In the plot of $[\text{Mg}/\text{Si}]$ versus $[\text{Fe}/\text{H}]$, the planet-hosting stars and the stars without planets have a similar scatter, namely 0.068 and 0.079, respectively. Unfortunately, in our sample there are no stars with low-mass planets close to the Earth-size ones. Nevertheless, the star with the smallest $[\text{Mg}/\text{Si}]$ ratio hosts the planet (HD 156668) with the lowest mass in this sample (0.01 M_J).

3.3 Iron-peak elements

For the iron-peak elements manganese and nickel (Figs. 5, 6) we see no significant difference either. This contradicts the study Kang, Lee & Kim (2011), which reported some differences in the manganese abundances between the stars with and without planets.

3.4 Oxygen, sulphur and zinc

These elements are singled out for special attention as they are assigned to volatile elements and have been investigated in numerous studies (e.g. Gonzalez 1997; Smith, Cunha & Lazzaro 2001; Meléndez et al. 2009, etc).

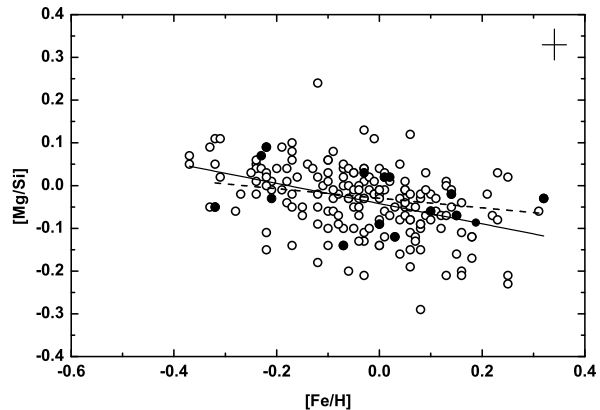


Figure 7. Dependence of $[\text{Mg}/\text{Si}]$ on $[\text{Fe}/\text{H}]$ for our target stars. Designations are as in Fig. 1.

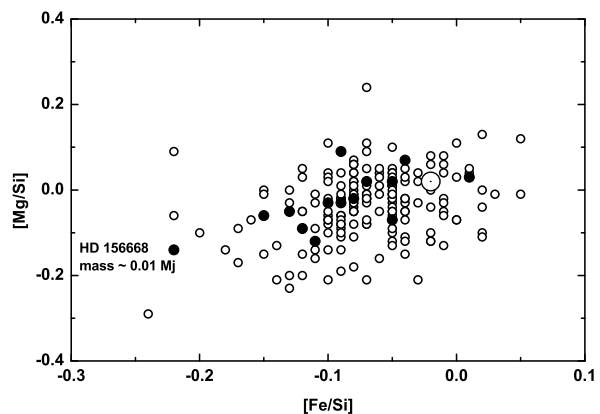


Figure 8. Dependence of $[\text{Mg}/\text{Si}]$ on $[\text{Fe}/\text{Si}]$ for our target stars. Designations are as in Fig. 1. The solar value is marked as a circle with a point.

Higher abundance of volatile elements compared with the solar-analogue stars and solar twins with giant planets can be a sign of the presence of Earth-like planets. In a study of the difference between the solar photospheric abundance and elemental abundance in B stars and nearby F-G dwarfs, Gonzalez (1997) plotted solar and stellar abundances against the condensation temperature T_{cond} . The condensation temperature of a given element is the temperature in a gaseous environment at which half of the element's atoms condense out of the gas plane, usually on to grains. The gas-phase abundances in the interstellar medium correlate strongly with T_{cond} so that the elements with higher T_{cond} have the lowest gas-phase abundances. An increase in the relative content of volatile elements as compared with the solar-analog stars and solar twins with giant planets can be indicative of the presence of Earth-like planets. A comparison of the behavior of these elements depending on T_{cond} in the stars with and without planets will be presented below (Sect.4). A direct comparison of the abundances of the indicated elements with the metallicity does not show any significant differences (see Fig.5).

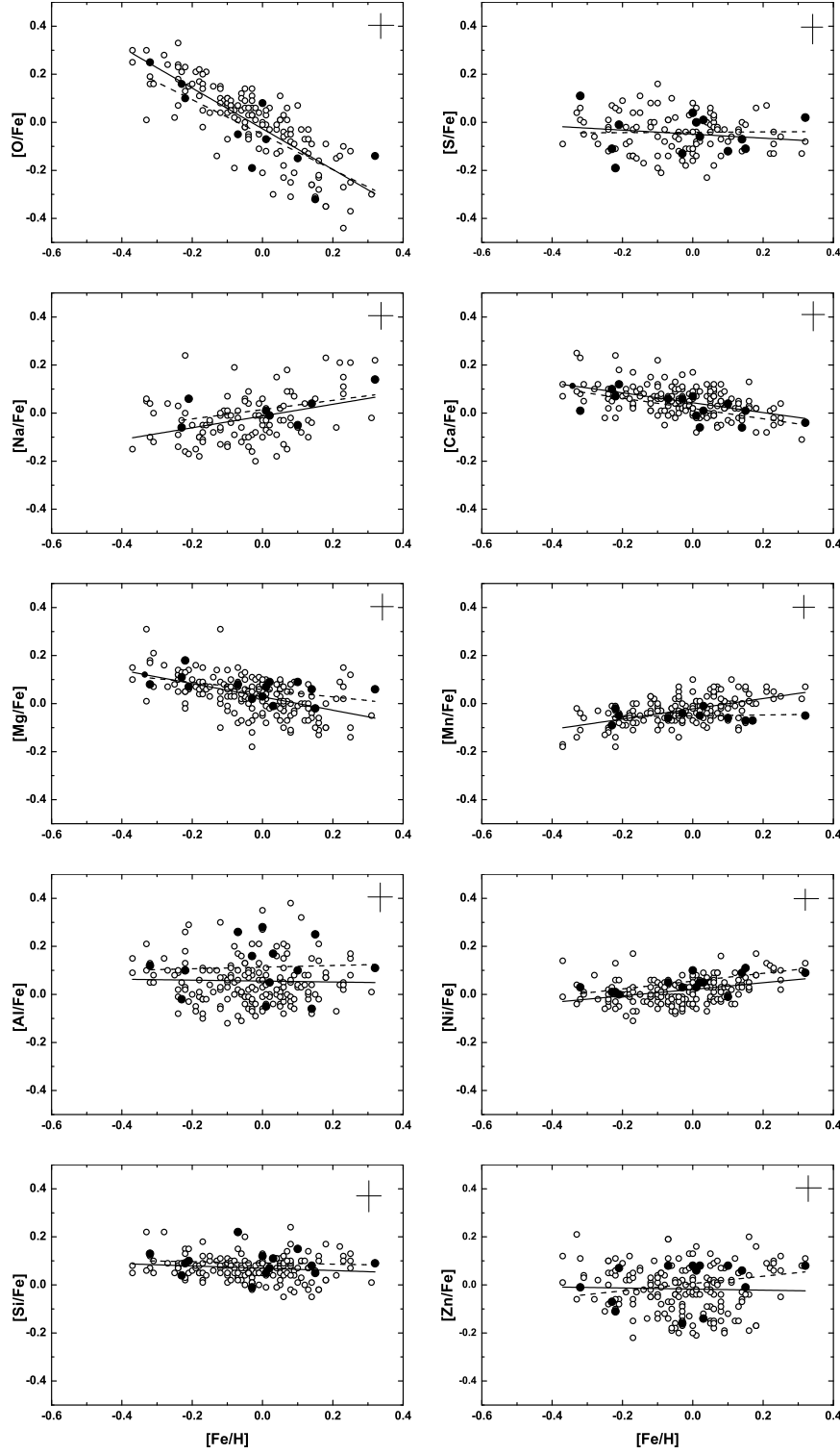


Figure 5. Abundance $[El/Fe]$ trend versus metallicity $[Fe/H]$.

3.5 Neutron-capture elements

The neutron-capture elements show no significant differences in trends; the observed differences are within the errors (Fig.6). However, there is one exception, which is a surprise, namely barium. This element shows a markedly different be-

haviour in the stars with and without planets. However, the results obtained require further verification.

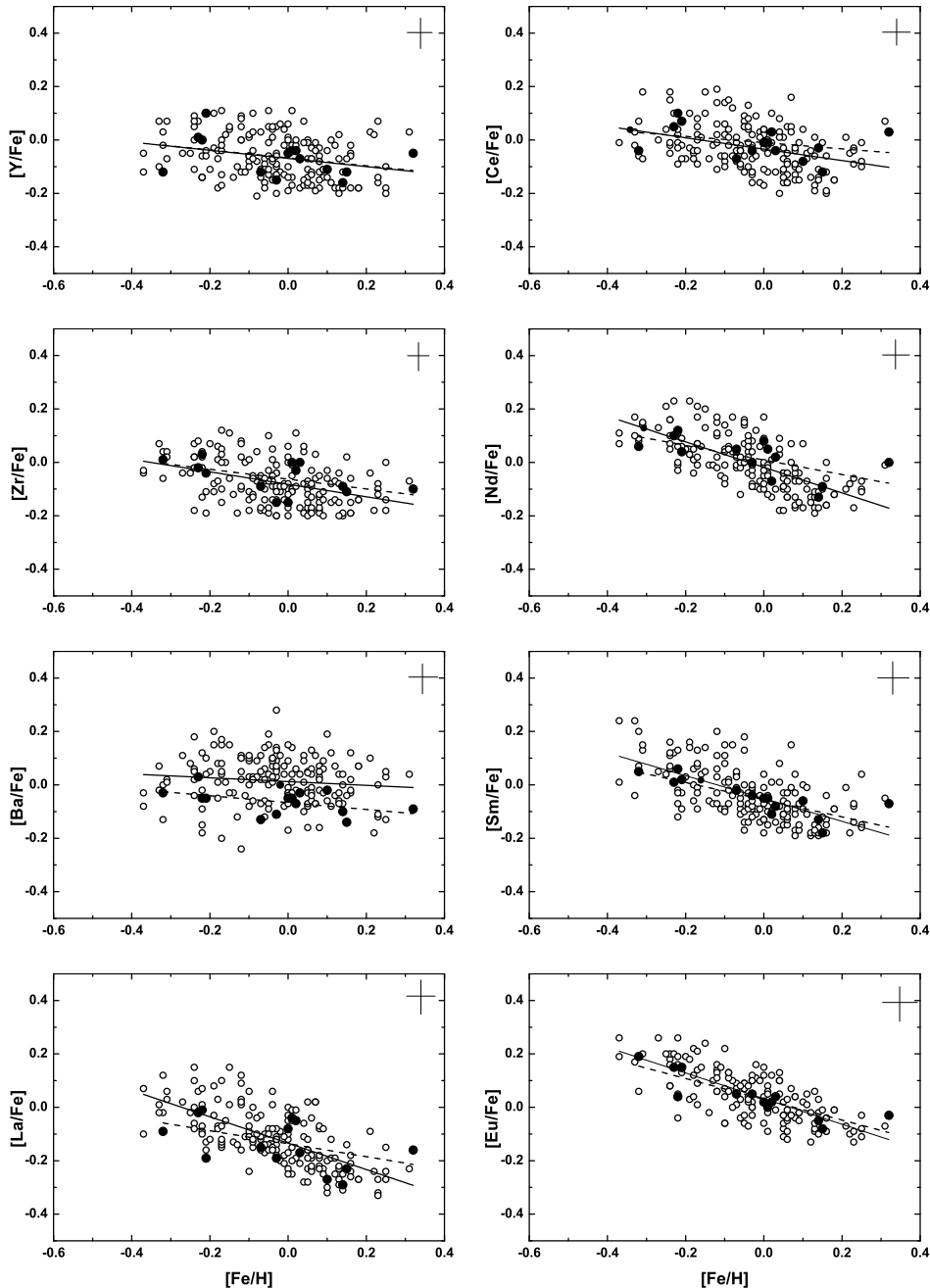


Figure 6. Abundance $[El/Fe]$ trend versus metallicity $[Fe/H]$.

4 THE DEPENDENCE OF THE ELEMENTAL ABUNDANCES ON THE CONDENSATION TEMPERATURE T_{COND}

Meléndez et al. (2009) found that volatile elements (having low T_{cond}) are more abundant in the Sun relative to in Solar twins while elements that easily form dust (elements with high T_{cond} , i.e., refractories) are underabundant. Previous attempts to trace T_{cond} -dependent abundance differences for stars known to host giant planets have not convincingly demonstrated significant differences (Udry & Santos 2007). González Hernández et al. (2013) revisit the sample of solar analogs, in particular, eight stars hosting super-Earth-like planets. Only four of them display clear increasing

abundance trends with T_{cond} . The authors suggested that there is no clear evidence supporting the hypothesis that the volatile-to-refractory abundance ratio is related to the presence of rocky planets. Adibekyan et al. (2014, 2015a) found that the chemical peculiarities (i.e. small refractory-to-volatile ratio) of planet-hosting stars is probably a consequence of their older age and their inner Galaxy origin. They conclude that the stellar age and probably the Galactic birthplace are key to establish the abundances of some specific elements. Nissen (2015) indicated that the dependence of $[El/Fe]$ on stellar age and the $[Ni/Fe]$ – $[Na/Fe]$ variations complicate the use of the $[El/Fe]$ – T_{cond} relation as a possible signature for the existence of terrestrial plan-

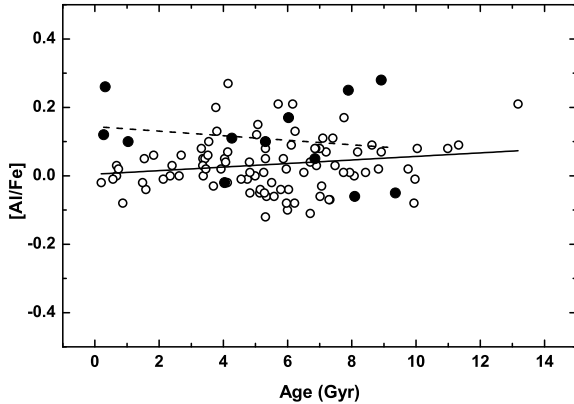


Figure 9. Dependence of $[Al/Fe]$ on age for our target stars. Designations are as in Fig. 1.

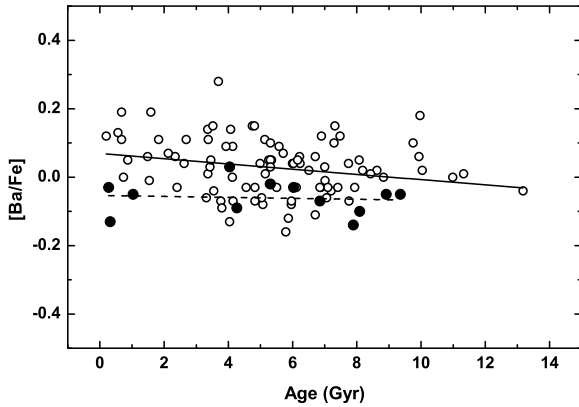


Figure 10. Dependence of $[Ba/Fe]$ on age for our target stars. Designations are as in Fig. 1.

ets around stars. He assumed that the age trends for the various abundance ratios provide new constraints on supernovae yields and Galactic chemical evolution. Note that Spina, Meléndez & Ramírez (2016) claimed that it is possible to disentangle the signature of planets and chemical evolution. We also have made an attempt to compare the volatile and refractory element abundances in solar twins and planet-hosting stars with the temperatures in the range 5750–5900 K.

4.1 16 Cyg A (HD186408) and 16 Cyg B (HD186427)

The star 16 Cyg is a well-known and well-studied binary system, with one component having one planet (16 Cyg B) and the other one (16 Cyg A) without a detected planet (e.g. Friel et al. 1993; Cochran et al. 1997; Deliyannis et al. 2000; Tucci Maia, Meléndez & Ramírez 2014). Both stars are included in our stellar sample. A comparison of stellar parameters with those of other authors (Deliyannis et al. 2000; Tucci Maia, Meléndez & Ramírez 2014) is presented in Table 6.

We obtained a good agreement between these indepen-

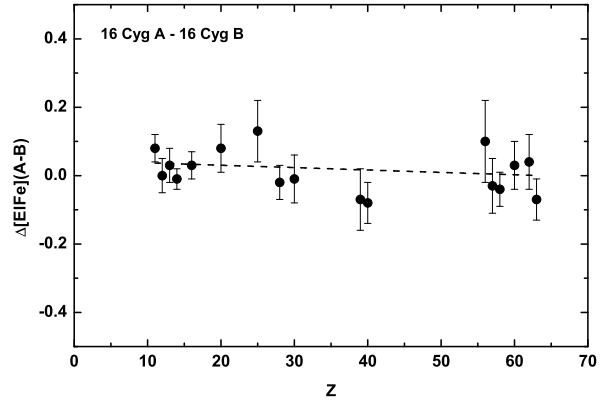


Figure 11. Dependence of $\Delta[El/Fe]$ on Z for 16 Cyg A and B.

dent determinations. 16 Cyg B is cooler than 16 Cyg A, and its $[Fe/H]$ is slightly lower than that of 16 Cyg A.

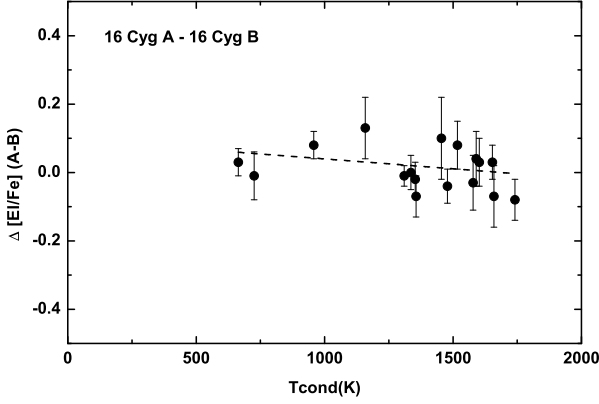
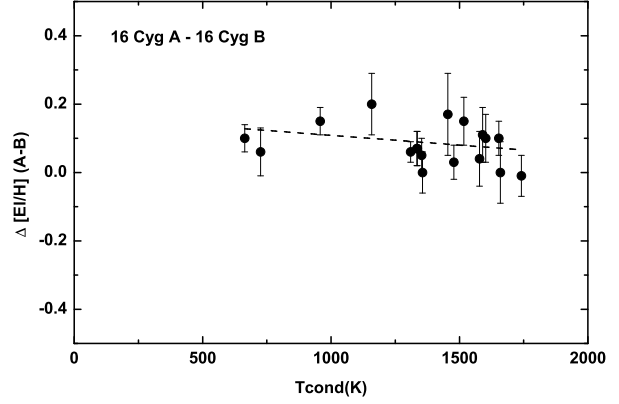
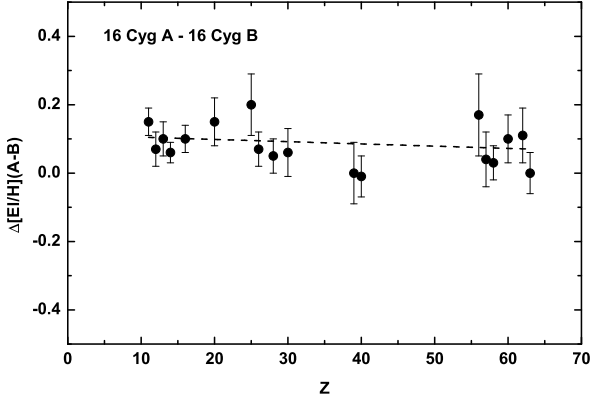
The lithium abundance is different in these two stars: we obtained the upper limit of lithium abundance for 16 Cyg B as $\log A(Li) < 0.80$ and the lithium abundance for 16 Cyg A is $\log A(Li) = 1.45$. The lithium abundance of the star with the detected planet is lower than that of the star without a planet. This is in agreement with the results of Deliyannis et al. (2000). The lithium abundance difference may be due to the accretion of planetary material by the A component, as proposed by (Deliyannis et al. 2000). It should be noted that there is no consensus on the results for this system (Laws & Gonzalez 2001; Takeda 2005; Schuler et al. 2011; Tucci Maia, Meléndez & Ramírez 2014).

The trend for the abundance difference $\Delta[El/Fe]$ with the atomic number Z and with the condensation temperature T_{cond} for these two stars is presented in Figs. 11, 12. As can be seen from these figures, there is no apparent trend of the difference in elemental abundances with either atomic number or the condensation temperature for these two stars. Hence, we cannot confirm the results obtained in (Tucci Maia, Meléndez & Ramírez 2014) for this system. For 16 Cyg A and B, these authors found that all elements showed abundance differences between the binary components. However, while the difference for volatile elements is about 0.03 dex, the refractory abundance difference is larger, and the latter showed a trend with condensation temperature, which could be interpreted as the signature of a rocky accretion core in the giant planet 16 Cyg Bb. However, it should be noted that the quality of our data is not very high; hence, we cannot provide better constraints than those given in our previous works.

We also examined the trends for abundance differences relative to hydrogen $\Delta[El/H]$ with the atomic number Z and with condensation temperature T_{cond} for these two stars (Figs. 13, 14). In this case, using $[El/H]$, we obtained a slope similar to the one for $[El/Fe]$ ($-5.71E-5$ with standard error $SE = 5.42E-5$). However, the star without a planet, 16 Cyg A, exhibits high elemental abundances compared with the planet-hosting star 16 Cyg B, with average values $\langle [El/H](A-B) \rangle = 0.08 \pm 0.02$ and $\langle [El/Fe](A-B) \rangle = 0.01 \pm 0.02$. The overabundance relative to hydrogen is slightly higher than the determination errors (0.07 dex of that sur-

Table 6. Parameter comparison for the stars 16 Cyg A and 16 Cyg B .

Star	HD	T_{eff} (K)	$\log g$	[Fe/H]	references
16 Cyg A	186408	5803 ± 4	4.20 ± 0.15	0.09 ± 0.08	our
—	—	5795 ± 20	4.30 ± 0.06	0.04 ± 0.02	Deliyannis et al. (2000)
—	—	5830 ± 7	4.30 ± 0.02	0.101 ± 0.008	Tucci Maia, Meléndez & Ramírez (2014)
16 Cyg B	186427	5752 ± 4	4.20 ± 0.15	0.02 ± 0.08	our
—	—	5760 ± 20	4.40 ± 0.06	0.06 ± 0.02	Deliyannis et al. (2000)
—	—	5751 ± 6	4.35 ± 0.02	0.054 ± 0.008	Tucci Maia, Meléndez & Ramírez (2014)

**Figure 12.** Dependence of $\Delta[\text{El}/\text{Fe}]$ on T_{cond} for 16 Cyg A and B.**Figure 14.** Dependence of $\Delta[\text{El}/\text{H}]$ on T_{cond} for 16 Cyg A and B.**Figure 13.** Dependence of $\Delta[\text{El}/\text{H}]$ on Z for 16 Cyg A and B.

plus is a result of the difference in the iron abundance obtained for the two stars, $[\text{Fe}/\text{H}]_{\text{A}} = 0.09$ and $[\text{Fe}/\text{H}]_{\text{B}} = 0.02$.

4.2 HD 38858, 95128, 189733, 217014

Fig. 15 shows the dependence of the difference of the elemental abundances in planet-hosting stars between the mean abundance of solar twin stars and T_{cond} for four stars whose parameters are similar to solar (HD 38858, 95128, 189733, 217014=51 Peg). These stars have massive planets whose masses range from $0.1 M_J$ to $2 M_J$. It can be seen that the dependence for HD217014 (51 Peg) ($M \sim 0.5 M_J$) exhibits a noticeable slope, while the correlations for HD 38858 ($M \sim$

Table 7. Linear fitting parameters (slope and standard error) for $\Delta[\text{El}/\text{Fe}]$ versus T_{cond} .

Star	HD	slope	st.error
16 Cyg (A-B)	186408/186427	$-5.77\text{E-}5$	$5.59\text{E-}5$
—	38858	$-1.11\text{E-}6$	$3.76\text{E-}5$
47 UMa	95128	$-1.54\text{E-}5$	$4.53\text{E-}5$
—	189733	$7.66\text{E-}5$	$4.95\text{E-}5$
51 Peg	217014	$-2.11\text{E-}4$	$6.30\text{E-}5$

$0.1 M_J$) and HD 95128 (with two known planets with masses $1.6 M_J$ and $0.5 M_J$) do not exhibit any slope. Volatile elements (low T_{cond}) are more abundant in 51 Peg relative to solar twins, while refractory elements (high T_{cond}) (which may form rocky cores of massive planets) are underabundant. HD189733 also shows a slope of $\Delta[\text{El}/\text{Fe}]$ (star-solar twins) dependence on T_{cond} , but with the opposite sign. Table 7 presents the linear fitting parameters for $\Delta[\text{El}/\text{Fe}]$ versus T_{cond} for the above-mentioned stars.

There are several possible explanations for the results obtained: for each star investigated for the presence of planets, an individual approach for the chemical composition analysis is required, as stars were formed in different areas of the Galactic disc with different pre-stellar elemental abundances (as indicated by Adibekyan et al. (2014)); or because it is evidence of the supernovae yields and Galactic chemical evolution (Nissen 2015).

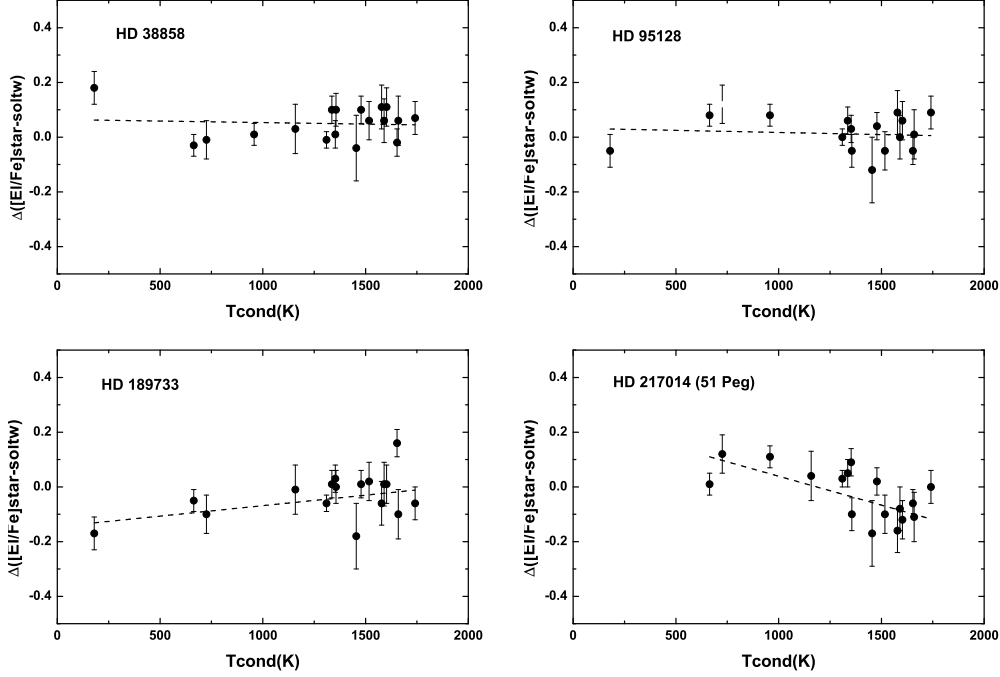


Figure 15. Dependences of $\Delta[\text{El}/\text{Fe}](\text{star-solar twins})$ on T_{cond} for planet-hosting stars similar to the Sun.

5 CONNECTION WITH CHEMICAL ENRICHMENT OF DIFFERENT GALACTIC SUBSTRUCTURES

All of the presented comparisons were made for the stars in the thin disc of the Galaxy, as the 14 selected planet-hosting stars are thin-disc stars. The association of the stars in our data base with Galactic substructures (thin and thick discs and halo) was determined earlier by us using kinematic criteria. The trends of $[\text{El}/\text{Fe}]$ versus $[\text{Fe}/\text{H}]$ are typical for thin-disc stars. Thus, in particular, an increasing of the magnesium abundance with metallicity was observed for the thin-disc stars, but to a lesser degree than for those of the thick disc. For Al and Ba, we investigated the dependences $[\text{Al}/\text{Fe}]$ and $[\text{Ba}/\text{Fe}]$ on age (Figs. 9, 10). We can see that the difference in the Al and Ba behaviour with age is very small, and is similar to that for metallicity.

The resulting difference in the barium behavior in the stars with and without planets could not be interpreted owing to the fact that the barium abundance depends on the age in the Galactic disc, as found by (e.g. Bensby et al. 2007). We were able to determine the real age for only five stars among 14 planet-hosting stars. The ages of these stars range from 5 to 9 Gyr. The age of the youngest is 5.31 Gyr and $[\text{Ba}/\text{Fe}] = -0.02$, the age of the oldest is 8.92 Gyr and $[\text{Ba}/\text{Fe}] = -0.05$. We see the same barium deficit for the planet-hosting stars of all ages in our sample. Furthermore, our previous studies did not find a clear correlation between the barium abundance and the age in the thin disc, which is, in our opinion, a result of the dispersion of metallicity in the thin disc. Moreover, our previous studies of the barium abundances in open cluster stars showed wide variation of the barium content from cluster to cluster, as well as higher barium abundances in young clusters (Mishenina et al. 2013, 2015b).

6 RESULTS AND DISCUSSION

Using homogeneous spectral data and techniques for determination of parameters and abundances of a number of elements, we compared results obtained for stars with and without planets. We have examined a total of about 200 stars, including 14 planet-hosting stars. Our main findings are as follows.

- The lithium abundances in planet-hosting solar-analog stars (i.e. stars with parameters very similar to the solar) in our small sample were lower than those in the stars for which no planetary systems had been discovered. The lithium abundance does not exceed 1.7 according to the scale where hydrogen is 12.0, except one star, namely HD 9826.
- For the binary star 16 Cyg, the star with a planet (16 Cyg B) has a lower lithium abundance than its companion without a detected planets.
- No significant differences, exceeding determination errors, for the abundances of other elements were found between stars with and without planets, with possible exception for aluminum and barium abundances.
- No statistically significant dependences of abundance differences in $[\text{El}/\text{Fe}]$ and $[\text{El}/\text{H}]$ with the condensation temperature T_{cond} for the two stars in the 16 Cyg binary system were found; it was not possible to determine the slope in 16 Cyg because of the large error bars.
- The abundance difference $\langle [\text{El}/\text{H}](\text{A-B}) \rangle = 0.08 \pm 0.02$ for the two stars shows a slight surplus, the origin of which is not clear.
- A slight excess of volatile elements and a deficit of refractories as compared with solar twins were obtained for 51 Peg (HD 217014).

The chemical composition of stars as well as atmo-

spheric parameters are important diagnostic tools in studies of stellar evolution, nucleosynthesis computations, and studies of various physical processes both inside stars and on their surfaces, etc. The application of chemical composition analysis always requires careful consideration of the origin of the chemical composition and the mechanisms of its change. As noted above, much attention has been paid recently to the investigation of any correlation between the abundance of one or another element and the presence of planetary systems around stars.

Metallicity. It is now clear that massive planets are observed preferentially around stars with solar or higher metallicities (Fischer & Valenti 2005; Sousa et al. 2008), while Earth-like planets can be hosted by stars with different metallicities (Sousa et al. 2008; Adibekyan et al. 2012a,b; Buchhave et al. 2012). Our current sample contains several stars hosting Jupiter-like planets. Among them there is the only star (HD 154345) that hosts a single planet with mass $M = 1M_J$. The most metal-poor planet-hosting star in our sample has the metallicity of ~ -0.3 dex and host a low-mass planet with a mass of $\sim 6.5 M_\oplus$ (HD 97658). The requirement of high metallicity may be a significant factor for the presence of massive planets, but this is not the case for less massive planets.

Lithium. This element is exposed to the effects of a number of factors to the larger extent than iron, which results in its abundance variations. In general, the lithium abundance is found to be lower in planet-hosting stars (Gonzalez & Laws 2000; Gonzalez 2008; Gonzalez, Carlson & Tobin 2010; Israelian et al. 2004, 2009; Delgado Mena et al. 2014; Figueira et al. 2014; Delgado Mena et al. 2015, etc.). The depletion of lithium owing to convection is observed in the stars with low temperatures (T_{eff} is lower than 5600 K) (e.g. Randich 2010). With temperatures close to solar and higher, the change in the lithium abundance is caused by the chromospheric activity (e.g. Tatischeff & Thibaud 2007) and (or) stellar rotation Charbonnel, Vauclair & Zahn (1992). It should also be noted that many authors (e.g. Baumann et al. 2010; Carlos, Nissen & Meléndez 2016, etc) have found strong evidence for increasing lithium depletion with age. The low lithium abundance determinations obtained by us for stars with massive planetary systems sustain the hypothesis regarding lithium depletion during the formation of stars, but do not preclude the possibility of specific enrichment of the pre-stellar cloud from which the star was formed. The number of stars in our sample is not high enough to assert the presence of dependence of the lithium abundance on the age of stars.

Volatile and refractory elements. The abundance determinations for elements with various condensation temperatures T_{cond} in parent stars, which could be depleted during the formation of planets, means that we can suggest the possibility of the formation of rocky Earth-like planets or of rocky cores of massive planets (e.g. Gonzalez 1997; Smith, Cunha & Lazzaro 2001; Meléndez et al. 2009, etc). Our data showed the presence of a trend (a slope of the plotted dependence) for the relative elemental abundances (star – mean elementary abundances in solar twins) with T_{cond} only for one star among four. Thus, for the star HD 217014 (51 Peg) we found a slight excess of volatile elements and a deficit of refractories as compared with those obtained

for the solar twins. It should be noted that 51 Peg has an age that is similar to the solar value (e.g. Israelian et al. 2004). The absence of such correlation for other three stars just sustains the assumption that the stellar chemical composition can be reckoned as better reflection of the chemical and dynamic evolution of the Galaxy, in particular the enrichment of the star's place of origin by supernovae of different types at the given time intervals (Adibekyan et al. 2014; Nissen 2015).

Other elements. Kang, Lee & Kim (2011) claimed different manganese abundance between the star with and without planets. Our studies have not confirmed any difference in the Mn abundances for our sample stars with and without planets (Kang, Lee & Kim 2011); however, we found that aluminium is more abundant while barium is less abundant in the stars with planetary systems. This fact requires further verification and confirmation.

Using our data base, we can corroborate independently that the chemical composition is undoubtedly an important, albeit an auxiliary, factor to be taken into account when studying the presence and formation of planetary systems. On the one hand statistical approaches (based on relative studies) for large samples of stars are required; on the other hand it is necessary to investigate each single star and each chemical element individually.

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Appendix

Table A1. Comparison of atmospheric parameters for each hosting planet stars in our sample with the data of other authors

HD	T_{eff} (K)	$\log g$	[Fe/H]	sources
3651	5277	4.50	0.15	our
	5182	4.30	0.12	Santos et al. (2013)
	5303	4.56	0.18	Ramírez et al. (2012)
	5252	4.32	0.19	Ghezzi et al. (2010)
	5196	4.49	0.20	Maldonado et al. (2012)
7924	5165	4.40	-0.22	our
	5133	4.46	-0.22	Santos et al. (2013)
	5233	4.50	-0.20	Maldonado et al. (2012)
9826	6074	4.00	0.10	our
	6212	4.26	0.13	Santos et al. (2013)
	6155	4.09	0.02	Ramírez et al. (2012)
	6153	4.28	0.11	Maldonado et al. (2012)
	6089	4.01	0.07	Takeda (2007)
	6140	4.12	0.12	Gonzalez & Laws (2000)
38858	5776	4.30	-0.23	our
	5733	4.51	-0.22	Santos et al. (2013)
	5719	4.49	-0.23	Tsantaki et al. (2013)
	5733	4.51	-0.22	Adibekyan et al. (2012a)
	5660	4.36	-0.27	Maldonado et al. (2012)
87883	5015	4.40	0.00	our
	4958	4.56	0.07	Santos et al. (2013)
	5000	4.62	0.14	Maldonado et al. (2012)
95128	5887	4.30	0.01	our
	5954	4.44	0.06	Santos et al. (2013)
	5894	4.30	0.02	Ramírez et al. (2012)
	5900	4.36	0.03	Kang, Lee & Kim (2011)
	5749	4.26	-0.03	Maldonado et al. (2012)
	5888	4.3	0.01	Takeda (2007)
	5892	4.27	0	Zhao & Gehren (2000)
	5731	4.16	-0.12	Chen et al. (2000)
97658	5136	4.50	-0.32	our
	5137	4.47	-0.35	Santos et al. (2013)
128314	4960	4.40	0.03	our
	4778	4.35	-0.03	Santos et al. (2013)
	5120	4.49	0.01	Ghezzi et al. (2010)
	4906	4.32	0.04	Maldonado et al. (2012)
145675	5406	4.50	0.32	our
	5311	4.42	0.43	Santos et al. (2013)
	5312	4.43	0.46	Maldonado et al. (2012)
	5309	4.45	0.44	Takeda (2007)
154345	5503	4.30	-0.21	our
	5468	4.54	-0.10	Santos et al. (2013)
	5452	4.54	-0.08	Kang, Lee & Kim (2011)
	5461	4.59	-0.06	Maldonado et al. (2012)
156668	4850	4.20	-0.07	our
	4867	4.38	-0.04	Santos et al. (2013)
186427	5752	4.20	0.02	our
	5772	4.40	0.08	Santos et al. (2013)
	5713	4.31	0.04	Ramírez et al. (2012)
	5780	4.44	0.09	Kang, Lee & Kim (2011)
	5680	4.37	0.01	Maldonado et al. (2012)
	5795	4.44	0.11	Takeda (2007)
	5760	4.40	0.06	Deliyannis et al. (2000)
189733	5076	4.40	-0.03	our
	5109	4.69	0.03	Santos et al. (2013)
	5111	4.59	-0.04	Torres et al. (2012)
	5201	4.64	0.02	Ghezzi et al. (2010)
217014	5778	4.20	0.14	our
	5858	4.44	0.24	Bensby, Feltzing & Oey (2014)
	5804	4.42	0.20	Santos et al. (2013)
	5822	4.43	0.18	Maldonado, Villaver & Eiroa (2013)
	5752	4.32	0.19	Ramírez et al. (2012)
	5739	4.17	0.19	Ghezzi et al. (2010)
	5830	4.50	0.24	Kang, Lee & Kim (2011)
	5710	4.15	0.11	Maldonado et al. (2012)
	5755	4.33	0.22	Takeda (2007)

Table A2. Abundance of hosting planet stars

HD	T_{eff} (K)	$\log g$	[Fe/H]	Li	Li_{HP}	[O/Fe]	[Na/Fe]	[Al/Fe]	[Mg/Fe]	[S/Fe]	[Si/Fe]	[Ca/Fe]	[Mn/Fe]	[Ni/Fe]	[Zn/Fe]
3651	5277	4.5	0.15	—	−0.52	−0.32	—	0.25	−0.02	−0.11	0.05	0.01	0.07	0.11	−0.01
7924	5165	4.4	−0.22	—	−0.30	0.10	—	0.10	0.18	−0.19	0.09	0.07	−0.03	0.01	−0.11
9826	6074	4.0	0.10	2.23	—	−0.15	−0.05	0.10	0.09	−0.12	0.15	0.04	−0.07	−0.01	0.08
38858	5776	4.3	−0.23	1.6	—	0.16	−0.06	−0.02	0.11	−0.11	0.04	0.10	−0.01	0.01	−0.07
87883	5015	4.4	0.00	—	—	0.08	—	0.28	0.03	0.04	0.12	0.07	—	0.10	0.08
95128	5887	4.3	0.01	1.7	—	−0.07	0.01	−0.05	0.07	0.00	0.05	−0.01	—	0.03	0.06
97658	5136	4.5	−0.32	—	−0.3	0.25	—	0.12	0.08	0.11	0.13	0.01	—	0.03	−0.01
128311	4960	4.4	0.03	—	−0.3	—	—	0.17	−0.01	0.01	0.11	0.01	−0.06	0.05	−0.14
145675	5406	4.5	0.32	—	0.5	−0.14	0.14	0.11	0.06	0.02	0.09	−0.04	0.07	0.09	0.08
154345	5503	4.3	−0.21	—	0.5	—	0.06	—	0.07	−0.01	0.10	0.12	−0.04	0.00	0.07
156668	4850	4.2	−0.07	—	0	−0.05	—	0.26	0.08	—	0.22	0.06	−0.05	0.05	0.08
186427	5752	4.2	0.02	—	—	—	−0.01	0.05	0.09	−0.06	0.07	−0.06	−0.03	0.05	0.08
189733	5818	4.3	−0.03	—	−0.35	−0.19	—	0.16	0.02	−0.13	−0.01	0.06	−0.05	0.03	−0.16
217014	5778	4.2	0.14	1.35	—	—	0.04	−0.06	0.06	−0.07	0.08	−0.06	0	0.09	0.06

Table A2 (continued)

HD	T_{eff} (K)	$\log g$	[Fe/H]	[Y/Fe]	[Zr/Fe]	[Ba/Fe]	[La/Fe]	[Ce/Fe]	[Nd/Fe]	[Sm/Fe]	[Eu/Fe]
3651	5277	4.5	0.15	−0.12	−0.11	−0.14	−0.23	−0.12	−0.09	−0.18	−0.08
7924	5165	4.4	−0.22	0.00	0.03	−0.05	−0.01	0.10	0.12	0.06	0.04
9826	6074	4.0	0.10	−0.11	—	−0.02	−0.27	−0.08	—	−0.06	—
38858	5776	4.3	−0.23	0.01	−0.02	0.03	−0.02	0.05	0.10	0.01	0.15
87883	5015	4.4	0	−0.05	−0.15	−0.05	−0.08	−0.01	0.08	−0.05	0.02
95128	5887	4.3	0.01	−0.04	0.00	−0.05	−0.04	−0.01	0.05	−0.05	0.00
97658	5136	4.5	−0.32	−0.12	0.01	−0.03	−0.09	−0.04	0.06	0.05	0.19
128311	4960	4.4	0.03	−0.07	0.00	−0.03	−0.17	−0.04	0.02	−0.08	0.04
145675	5406	4.5	0.32	−0.05	−0.10	−0.09	−0.16	0.03	0.00	−0.07	−0.03
154345	5503	4.3	−0.21	0.10	−0.04	−0.05	−0.19	0.07	0.04	0.02	0.15
156668	4850	4.2	−0.07	−0.12	−0.09	−0.13	−0.15	−0.07	0.05	−0.02	0.05
186427	5752	4.2	0.02	−0.04	−0.03	−0.07	−0.05	0.03	−0.07	−0.11	0.02
189733	5818	4.3	−0.03	−0.15	−0.15	−0.11	−0.19	−0.04	0.00	−0.04	0.05
217014	5778	4.2	0.14	−0.16	−0.09	−0.10	−0.29	−0.03	−0.13	−0.13	−0.05

Table A3. Abundance of stars without planets (Li-Zn). Solar-analogue stars are marked by asterisks.

HD	T_{eff} (K)	$\log g$	[Fe/H]	Li	li_{up}	[O/Fe]	[Na/Fe]	[Al/Fe]	[Mg/Fe]	[S/Fe]	[Si/Fe]	[Ca/Fe]	[Mn/Fe]	[Ni/Fe]	[Zn/Fe]
166	5514	4.6	0.16	2.24	—	-0.23	—	-0.02	-0.13	—	-0.02	0.03	0.01	0.02	0.04
1562	5828	4.0	-0.32	1.9	—	0.16	0.04	0.13	0.18	0.01	0.07	0.23	-0.04	-0.02	-0.01
1835	5790	4.5	0.13	2.55	—	-0.07	-0.10	0.00	0.00	-0.04	0.07	0.02	0.07	0.03	0.05
3651	5277	4.5	0.15	—	-0.52	-0.32	—	0.25	-0.02	-0.11	0.05	0.01	0.07	0.11	-0.01
4256	5020	4.3	0.08	—	-0.40	-0.25	—	0.38	0.08	—	0.17	0.12	0.06	0.16	0.07
4307	5889	4.0	-0.18	2.48	—	0.17	-0.10	0.06	0.06	-0.08	0.05	0.06	-0.06	0	0.02
4614	5965	4.4	-0.24	2.17	—	0.33	-0.09	0.09	0.10	-0.03	0.09	0.02	-0.04	0.02	0.10
5294	5779	4.1	-0.17	2.17	—	-0.02	-0.11	-0.02	0.08	-0.14	0.02	0.11	0.00	-0.03	0.03
7590*	5962	4.4	-0.10	2.73	—	-0.07	—	0.06	0.06	—	0.05	0.22	-0.01	-0.06	-0.14
7924	5165	4.4	-0.22	—	-0.30	0.10	—	0.10	0.18	-0.19	0.09	0.07	-0.03	0.01	-0.11
8648	5790	4.2	0.12	—	1.4	-0.07	0.04	0.04	0.00	—	0.10	0.02	0.02	0.09	0.11
9407*	5666	4.45	0.05	0.5	—	—	—	0.07	0.01	-0.04	0.05	0.03	-0.07	0.05	-0.02
9826	6074	4.0	0.10	2.23	—	-0.15	-0.05	0.10	0.09	-0.12	0.15	0.04	—	-0.01	0.08
10086	5696	4.3	0.13	1.65	—	-0.13	—	0.08	-0.02	—	-0.02	0.05	-0.11	0	-0.15
10307*	5881	4.3	0.02	1.95	—	-0.03	-0.08	-0.01	0.06	-0.08	0.05	-0.02	-0.01	0.06	0.08
10476	5242	4.3	-0.05	—	—	0.00	0.05	0.08	0.03	—	0.08	-0.02	-0.05	-0.01	0.01
10780	5407	4.3	0.04	—	—	-0.13	-0.09	0.02	0.04	—	-0.01	-0.02	-0.04	0.03	-0.02
11007	5980	4.0	-0.20	2.48	—	0.16	-0.05	0.00	0.10	0.09	0.06	0.07	-0.09	0	0.09
12051	5458	4.55	—	—	—	—	—	0.05	—	—	—	—	—	—	0
12856	5766	4.5	-0.24	—	0.07	0.07	—	0.10	0.14	—	0.08	0.08	-0.12	0	-0.08
13507*	5714	4.5	-0.02	2.4	—	0.06	-0.20	-0.09	-0.05	-0.04	0.05	0.01	-0.03	-0.02	0.06
14374	5449	4.3	-0.09	—	—	0.05	-0.01	0.11	0.07	—	0.08	0.08	—	0.01	-0.01
17674	5909	4.0	-0.14	1.7	—	0.15	-0.08	0.01	0.11	-0.17	0.06	0.08	-0.07	-0.03	-0.02
17925	5225	4.3	-0.04	—	—	-0.06	0.04	0.10	0.04	-0.07	0.05	0.10	0.07	0.03	0.01
18632	5104	4.4	0.06	—	-0.35	-0.18	—	0.21	0.01	—	0.09	0.12	0.07	0.05	-0.15
18803	5665	4.55	0.14	0.5	—	-0.26	—	0.04	-0.04	—	0.01	-0.02	0.00	0.04	-0.06
19019	6063	4.0	-0.17	—	1	0.05	-0.12	-0.02	0.15	-0.14	0.05	0.17	-0.05	-0.11	0.05
19373	5963	4.2	0.06	2.45	—	-0.06	-0.03	0.11	-0.03	0.03	0.08	-0.01	0.04	0.06	0.09
20630*	5709	4.5	0.08	2.08	—	-0.08	—	-0.01	-0.12	—	-0.02	0.04	-0.06	-0.03	-0.11
22049	5084	4.4	-0.15	—	—	0.04	-0.04	0.04	0.03	0.04	0.10	0.07	—	0.00	0.07
22484	6037	4.1	-0.03	—	—	0.14	-0.16	0.08	0.02	—	0.05	?	-0.04	-0.01	0.06
22556	6155	4.2	-0.17	2.53	—	0.14	-0.08	-0.1	0.07	-0.03	0.12	0.03	—	0.03	-0.15
24053*	5723	4.4	0.04	2.04	—	-0.03	-0.18	0.00	-0.01	0	0.07	-0.01	-0.02	-0.04	0.03
24206	5633	4.5	-0.08	1.53	—	0.05	-0.09	0.05	0.05	-0.08	0.07	-0.05	-0.04	0.05	0.04
24496	5536	4.3	-0.13	—	0	-0.14	—	0.10	0.14	—	0.1	0.12	-0.04	-0.03	-0.14
25665	4967	4.7	0.01	—	-0.40	-0.01	—	0.11	-0.08	—	0.04	-0.02	-0.08	0.08	0.16
25680*	5843	4.5	0.05	2.43	—	0.01	—	0.01	-0.07	—	0.00	0.08	-0.03	-0.02	-0.16
26923*	5920	4.4	-0.03	2.75	—	0.11	—	-0.03	0.11	—	-0.02	0.10	-0.07	-0.05	-0.15
28005	5980	4.2	0.23	—	1	-0.27	0.08	0.02	0.15	-0.13	0.12	-0.05	—	0.10	0.1
28447	5639	4.0	-0.09	2	—	0.07	-0.04	0.08	0.07	-0.21	0.10	0.01	-0.03	0.04	0.05
29150*	5733	4.3	0	—	1	—	-0.03	0.03	0.09	-0.16	0.05	0.00	-0.01	0.00	0.13
29310	5852	4.2	0.08	2.6	—	-0.03	-0.02	-0.03	0.00	-0.14	0.09	0.05	-0.01	-0.02	-0.07
29645	6009	4.0	0.14	2.6	—	-0.09	-0.04	-0.08	0.03	0.00	0.08	-0.03	-0.03	0.06	-0.03
30495*	5820	4.4	-0.05	2.32	—	0.09	-0.10	-0.04	0.06	-0.06	0.07	0.04	-0.03	-0.01	-0.04
33632	6072	4.3	-0.24	2.6	—	0.24	-0.14	-0.01	0.12	-0.02	0.07	0.06	-0.1	-0.05	0.05
34411	5890	4.2	0.1	2.12	—	0.07	-0.06	0.04	-0.01	-0.08	0.07	-0.03	0.00	0.03	0.08
37394	5296	4.5	0.09	—	0.00	-0.21	—	-0.02	-0.04	—	-0.03	0.02	0.01	-0.01	-0.2
39587*	5955	4.3	-0.03	2.75	—	—	-0.09	0.03	0.07	-0.16	0.06	0.02	-0.08	-0.07	-0.13
40616	5881	4.0	-0.22	2.2	—	-0.16	0.03	0.05	0.05	-0.11	0.02	0.08	-0.02	-0.03	0.11
41330	5904	4.1	-0.18	2	—	0.22	-0.18	0.01	0.04	-0.14	0.08	0.06	-0.04	-0.01	0.04
41593	5312	4.3	-0.04	—	—	0.03	-0.14	0.02	-0.08	—	0.05	0.05	0.03	-0.03	-0.05
42618*	5787	4.5	-0.07	1.1	—	0.07	—	0.10	0.07	—	0.03	0.04	-0.06	-0.01	-0.07
42807*	5719	4.4	-0.03	1.8	—	0.03	—	-0.07	0.03	—	-0.01	0.07	-0.04	-0.05	-0.08
43587	5927	4.1	-0.11	2.13	—	0.09	0.01	-0.07	0.08	0.00	0.08	0.07	0.02	0.06	0.10
43856	6143	4.1	-0.19	2.5	—	—	-0.15	-0.07	0.07	-0.02	0.08	0.08	-0.06	0.00	0.02
43947	6001	4.3	-0.24	2.35	—	0.23	-0.09	-0.08	0.12	-0.12	0.08	0.06	-0.11	-0.03	0.00
45067	6058	4.0	-0.02	2.5	—	0.01	-0.08	-0.04	0.04	-0.18	0.05	0.03	—	—	-0.04
45088	4959	4.3	-0.21	—	-0.50	—	—	0.29	0.14	—	0.15	0.18	—	0.06	-0.08
48682	5989	4.1	0.05	2.55	—	—	—	0.02	0.03	—	0.08	0.10	-0.05	-0.02	-0.15
50692*	5911	4.5	-0.10	1.95	—	0.1	—	0.09	0.07	—	0.01	0.06	-0.11	-0.01	-0.04
51419	5746	4.1	-0.37	—	0.8	0.3	-0.15	0.15	0.15	-0.09	0.08	0.12	-0.18	-0.01	0.12
51866	4934	4.4	0.00	—	-0.45	—	—	0.27	0.08	—	0.09	0.02	0.05	0.07	0.02
53927	4860	4.65	-0.22	—	0.00	—	—	0.02	-0.02	—	0.09	—	-0.18	0.06	-0.1

Table A3 (continued)

HD	T_{eff} (K)	$\log g$	[Fe/H]	Li	li_{up}	[O/Fe]	[Na/Fe]	[Al/Fe]	[Mg/Fe]	[S/Fe]	[Si/Fe]	[Ca/Fe]	[Mn/Fe]	[Ni/Fe]	[Zn/Fe]
54371	5670	4.2	0.06	1.97	—	-0.06	—	0.05	0.07	—	-0.05	0.09	—	-0.02	-0.18
55575	5949	4.3	-0.31	1.95	—	—	-0.12	0.08	0.21	0.00	0.10	0.05	—	0.01	0.04
58595	5707	4.3	-0.31	1.75	—	0.16	0.00	0.05	0.07	-0.05	0.05	0.12	-0.06	0.00	0.03
59747	5126	4.4	-0.04	1.40	—	—	—	0.07	0.05	—	0.05	0.06	0.05	-0.01	-0.2
61606	4956	4.4	-0.12	—	—	0.04	0.00	0.07	-0.10	—	0.08	0.01	0.03	-0.04	-0.05
62613	5541	4.4	-0.10	—	—	0.08	-0.14	-0.02	0.07	-0.06	0.04	-0.01	-0.03	0.02	-0.05
63433*	5693	4.35	-0.06	2.37	—	0.10	—	0.01	0.02	—	0.02	0.07	-0.11	-0.05	-0.19
64468	5014	4.2	0.00	—	0.10	—	—	0.35	0.10	—	0.13	0.17	0.10	0.08	-0.2
64815	5864	4.0	-0.33	—	1	0.01	0.05	0.21	0.31	0.04	0.22	0.25	-0.14	0.04	0.21
65874	5936	4.0	0.05	3.2	—	0.01	0.02	0.06	0.09	-0.01	0.08	0.05	0.06	0.06	0.13
68638	5430	4.4	-0.24	—	—	0.18	0.03	0.02	0.05	0.01	0.07	0.10	—	-0.02	0.1
70923	5986	4.2	0.06	2.45	—	0.03	0.03	-0.03	0.07	0.02	0.09	-0.01	—	0.07	0.02
71148	5850	4.2	0.00	1.95	—	—	-0.05	-0.06	0.03	0.08	0.05	0.00	—	0.01	0.03
72760	5349	4.1	0.01	—	—	0.05	-0.03	0.00	0.02	-0.14	-0.01	0.07	—	-0.06	-0.02
72905*	5884	4.4	-0.07	2.7	—	0.01	-0.02	0.06	0.09	-0.14	0.04	0.07	-0.07	-0.04	-0.14
73344	6060	4.1	0.08	2.65	—	—	0.09	-0.05	0.08	—	0.10	0.08	-0.05	0.03	0.02
75732	5373	4.3	0.25	—	—	-0.12	0.21	0.17	0.12	-0.06	0.10	0.04	—	0.10	0.12
75767	5823	4.2	-0.01	1.4	—	-0.11	—	0.13	0.11	—	0.00	0.08	-0.24	-0.04	-0.03
76151*	5776	4.4	0.05	1.75	—	—	0.02	-0.05	0.06	0.04	0.09	-0.01	—	0.05	0.08
81809	5782	4.0	-0.28	1.35	—	0.28	—	0.15	0.16	-0.06	0.22	0.10	—	0.08	-0.06
82443	5334	4.4	-0.03	2.60	—	0.09	—	0.03	-0.02	—	0.01	0.11	—	-0.06	-0.17
87883	5015	4.4	0.00	—	—	0.08	—	0.28	0.03	0.04	0.12	0.07	—	0.10	0.08
88072*	5778	4.3	0.00	1.65	—	-0.21	-0.02	-0.01	-0.05	-0.13	0.09	-0.01	—	0.03	-0.04
89251	5886	4.0	-0.12	—	0.5	—	-0.01	-0.06	0.05	-0.02	0.07	0.06	—	0.03	-0.02
89269	5674	4.4	-0.23	—	1	0.21	-0.03	0.05	0.13	0.07	0.09	0.05	—	0.03	0.05
94765	5077	4.4	-0.01	—	-0.20	0.04	—	0.21	0.06	—	0.05	0.05	—	0.03	-0.13
95128	5887	4.3	0.01	1.7	—	-0.07	0.01	-0.05	0.07	-0.09	0.05	-0.01	—	0.03	0.06
97334*	5869	4.4	0.06	2.55	—	-0.23	—	-0.01	-0.01	—	0.04	0.1	—	-0.03	-0.10
97658	5136	4.5	-0.32	—	-0.30	0.25	—	0.12	0.08	0.11	0.13	0.01	—	0.03	-0.01
98630	6060	4	0.22	—	0.5	-0.14	0.21	0.04	0.09	-0.13	0.16	0.01	—	0.12	0.07
101177	5932	4.1	-0.16	2.2	—	0.21	-0.05	-0.02	0.06	-0.15	0.04	0.09	-0.08	-0.07	-0.03
102870	6055	4	0.13	1.9	—	-0.03	-0.03	-0.02	0.08	-0.03	0.07	-0.02	-0.06	0.04	0.05
105631	5416	4.4	0.16	—	-0.30	-0.28	—	0.14	-0.06	—	-0.02	0.02	—	0.05	-0.19
107705	6040	4.2	0.06	2.7	—	-0.04	-0.13	-0.08	-0.10	0.00	0.09	0	-0.05	0.01	-0.04
108954	6037	4.4	-0.12	2.75	—	0.1	-0.13	-0.05	0.09	0.00	0.07	0.06	-0.03	-0.01	0.03
109358	5897	4.2	-0.18	1.7	—	0.11	-0.1	-0.01	0.09	—	0.05	0.06	-0.05	0.02	0.12
110463	4950	4.5	-0.05	0.80	—	-0.02	—	-0.01	0.03	—	0.00	0.13	-0.05	-0.07	-0.18
110833	5075	4.3	0.00	—	—	-0.01	0.06	0.06	-0.04	-0.04	0.10	0.02	—	0.05	0.00
111395*	5648	4.6	0.1	1.5	—	—	—	0.03	-0.01	—	0.01	0.03	-0.02	—	-0.12
114710*	5954	4.3	0.07	2.54	—	-0.05	-0.15	0	-0.07	-0.02	0.05	-0.05	-0.04	-0.02	0.01
115383	6012	4.3	0.11	2.64	—	-0.03	-0.08	0.03	0.04	-0.06	0.1	0.06	0.00	0.02	0.02
116956	5386	4.55	0.08	1.65	—	-0.31	—	0.06	-0.11	—	0.04	0.05	0.02	0.01	-0.15
117043	5610	4.5	0.21	—	0.5	-0.15	-0.06	-0.07	0.02	—	0.04	-0.08	0.05	0.13	0.09
119332	5246	4.45	-0.07	0.50	—	—	—	-0.09	0.07	—	0.05	-0.01	—	0.04	0.19
122064	4937	4.5	0.07	—	—	0.06	0.09	0.20	0.01	—	0.14	-0.06	0.06	0.09	0.00
125184	5695	4.3	0.31	—	1	-0.3	-0.02	0.01	-0.05	-0.13	0.01	-0.11	0.02	0.1	0.08
126053	5728	4.2	-0.32	1.4	—	0.19	-0.1	0.05	0.17	0.06	0.12	0.08	-0.11	-0.02	0.11
128311	4960	4.4	0.03	—	-0.30	—	—	0.17	-0.01	0.01	0.11	0.01	-0.06	0.05	-0.14
130307	4990	4.3	-0.25	—	-0.20	0.02	—	0.08	0.08	—	0.05	-0.02	-0.13	-0.06	-0.11
130948*	5943	4.4	-0.05	2.8	—	0.14	—	-0.01	0.02	—	0.04	0.09	-0.07	-0.08	-0.16
135204	5413	4.0	-0.16	—	—	—	—	—	—	—	—	—	—	—	—
135599	5257	4.3	-0.12	—	—	0.08	-0.07	0.02	0.00	—	0.05	0.04	0.03	-0.01	-0.05
137107	6037	4.3	0	2.6	—	0	-0.1	-0.07	0.05	-0.11	0.06	0.06	-0.07	-0.05	-0.03
139341	5242	4.6	0.21	—	—	—	—	—	—	0.07	—	—	—	—	—
139777*	5771	4.4	0.01	2.87	—	—	—	0.04	-0.01	-0.08	0.05	0.11	-0.04	-0.02	-0.21
139813	5408	4.5	0.00	2.35	—	—	—	0.06	0.01	—	0.09	0.09	—	-0.04	-0.17
140538*	5675	4.5	0.02	1.5	—	0.06	-0.05	0	-0.02	-0.08	0.05	0.09	0.01	0.05	-0.04
141004	5884	4.1	-0.02	1.95	—	—	-0.01	0.02	0.10	-0.11	0.08	0.02	-0.01	0.03	0
141272	5311	4.4	-0.06	0.50	—	—	—	0.01	0.04	—	0.07	0.05	-0.07	-0.02	-0.18
142267	5856	4.5	-0.37	—	-0.37	0.25	—	0.09	0.10	—	0.05	0.07	-0.17	0.14	0.01
144287	5414	4.5	-0.15	—	—	—	-0.03	0.10	0.07	0.11	0.12	0.10	—	0.00	0.06
145675	5406	4.5	0.32	—	0.50	-0.14	0.22	0.11	0.06	-0.08	0.09	-0.04	0.07	0.13	0.11
146233*	5799	4.4	0.01	1.6	—	-0.12	-0.07	-0.04	0.04	-0.04	0.05	-0.08	0.01	0.03	-0.02

Table A3 (continued)

HD	T_{eff} (K)	$\log g$	[Fe/H]	Li	Li_{up}	[O/Fe]	[Na/Fe]	[Al/Fe]	[Mg/Fe]	[S/Fe]	[Si/Fe]	[Ca/Fe]	[Mn/Fe]	[Ni/Fe]	[Zn/Fe]
149661	5294	4.5	-0.04	-	-	0.06	0.09	0.09	0.02	-0.04	0.09	0.05	-0.03	0.05	0.11
149806	5352	4.55	0.25	0.50	-	-0.25	-	0.15	-0.14	-	0.07	-0.02	0.03	0.02	0.06
151541	5368	4.2	-0.22	-	-	0.23	0.00	0.13	0.05	0.06	0.03	0.07	-0.06	-0.06	-0.06
152391	5495	4.3	-0.08	1.3	-	-	-	-	-	-0.03	-	-	-	-	-
154931	5910	4	-0.1	2.45	-	0.04	0.01	0.06	0.14	-0.19	0.08	0.12	-	0.05	0.04
155712	4932	4.6	-0.06	-	-0.50	-	-	0.16	-0.07	-	0.13	-	-	-0.01	-0.10
156668	4850	4.2	-0.07	-	0.00	-0.05	-	0.26	0.08	-	0.22	0.06	-0.05	0.05	0.08
159222*	5834	4.3	0.06	2	-	-	-	0.03	0.00	-0.02	0.08	0.07	-	0.03	0.01
159909	5749	4.1	0.06	-	1.3	-	-	-	-	-0.18	-	-	-	-	-
160346	4983	4.3	-0.10	-	-	0.1	0.07	0.03	-0.01	0.16	0.09	0.11	0.00	0.00	0.03
161098	5617	4.3	-0.27	1.1	-	0.24	0.04	0.10	0.07	-0.09	0.09	0.12	-0.03	-0.02	0.02
164922	5392	4.3	0.04	-	-	-0.01	0.15	0.16	0.08	-	0.11	0.12	0.03	0.07	-0.09
164922	5392	4.3	0.04	-	-	-	-	-	-	-0.23	-	-	-	-	-
165173	5505	4.3	-0.05	-	-	0.06	0.06	0.13	0.13	0.02	0.10	0.10	-0.01	0.04	0.02
165341	5314	4.3	-0.08	-	-	0.02	0.19	0.20	0.03	-	0.10	0.15	-	0.03	0.00
165476	5845	4.1	-0.06	-	-	0.05	-0.12	0.00	0.01	-0.10	0.04	0.00	-0.05	-0.04	-0.07
165670	6178	4	-0.1	1.4	-	0.07	-0.13	-0.12	-0.03	0.08	0.11	0.07	-0.07	0.01	-0.12
166620	5035	4.0	-0.22	-	-	0.13	0.24	0.18	0.13	-	0.13	0.24	-0.01	0.00	0.06
168009	5826	4.1	-0.01	-	0.5	-	0.04	0.09	0.03	-0.11	0.05	0.04	-	0.02	0.13
173701	5423	4.4	0.18	-	-	-0.09	0.23	0.09	0.00	0.06	0.17	-0.08	-	0.17	0.16
175742	5030	4.5	-0.03	-	0.00	-	-	0.10	-0.12	-	0.01	0.06	-0.07	-0.04	-0.09
176377	5901	4.4	-0.17	2.2	-	-	-	-0.08	0.04	-	0.18	0.04	-0.11	0.17	-0.22
176841	5841	4.3	0.23	1.9	-	-	0.11	0.05	0.07	-0.09	-	-0.02	0.05	-	0.09
178428	5695	4.4	0.14	-	0.2	-0.26	-	0.15	-0.06	-	-0.05	-0.01	0.00	0.03	-0.07
180161	5473	4.5	0.18	-	0.80	-0.35	-	0.07	-0.10	-	0.02	0.02	-	0.08	-0.17
180161	5473	4.5	0.18	-	0.8	-0.35	-	0.07	-0.1	-	0.02	0.02	0.00	0.08	-0.17
182488	5435	4.4	0.07	-	-	0.01	0.18	0.17	0.05	-	0.10	0.03	-	0.09	0.10
183341*	5911	4.3	-0.01	2.25	-	-0.05	-0.01	0.06	0.07	0.03	0.09	0.03	-0.05	0.01	0.07
184385	5619	4	0.12	0.5	-	-0.12	-	0.08	-0.07	-	0	0.02	-0.01	-0.04	-0.15
184768	5713	4.2	-0.07	-	1	-	0.01	0.17	0.15	0.01	0.15	0.03	-	0.06	0.11
185144	5271	4.2	-0.33	-	-	0.30	0.06	0.10	0.01	-	0.06	0.09	-0.02	-0.04	-0.06
185414*	5818	4.3	-0.04	2.13	-	-0.05	-	-0.06	0.05	-	0.08	0.02	-0.14	0.04	0.01
186104	5753	4.2	0.05	1.5	-	0.11	-0.03	0.07	0.06	-0.09	0.07	0.03	-	0.04	0.02
186408	5803	4.2	0.09	1.45	-	-	0.07	0.08	0.09	-0.03	0.06	0.02	0.01	0.03	0.07
187897*	5887	4.3	0.08	2.45	-	-	-0.05	-0.01	0.05	-0.07	0.08	-0.05	-0.03	0.02	-0.04
189087	5341	4.4	-0.12	-	-	0.14	-0.06	0.03	0.02	0.08	0.11	0.01	0.00	0.00	0.00
190007	5076	4.4	0.16	-	-0.50	-0.16	-	-	-0.11	-	0.10	0.13	-	0.03	-0.04
190406	5401	4.4	0.05	2.28	-	-0.12	-	-0.01	-0.02	-	0.02	0.09	-	0.03	-0.03
190470	5905	4.3	0.11	-	0.00	-	-	0.32	0.00	-	0.03	-0.04	0.10	-0.04	0.01
190771	5130	4.3	0.13	2.32	-	-	-	0.01	-0.07	-	0.14	0.04	-	0.06	-0.09
191533	6167	3.8	-0.10	2.75	-	0.08	-0.01	0.05	0.03	-0.14	0.09	0.12	-0.02	-0.03	0.01
191785	5766	4.3	-0.12	-	-0.25	0.15	-	0.3	0.31	-	0.07	0.15	-0.04	0.06	0.01
195005	6075	4.2	-0.06	2.7	-	0.12	-0.06	-0.11	0.12	0.1	0.08	0.11	-0.02	-0.07	0.08
195104	6103	4.3	-0.19	2.55	-	0.21	-0.15	-0.05	0.16	-0.09	0.07	0.1	-0.09	-0.09	-0.03
197076	5821	4.3	-0.17	2.2	-	0.16	-0.05	0.11	0.07	0.04	0.09	0.11	-0.03	0.01	-0.06
199960	5878	4.2	0.23	2.53	-	-0.44	0.15	0.04	0.02	-0.04	0.10	0.02	0.02	0.11	0.06
200560	5205	4.2	0.06	-	-0.40	-	-	0.15	-0.03	-	0.12	0.07	0.05	0.09	-0.16
202108	5712	4.2	-0.21	1.9	-	0.15	-0.17	-	-0.03	0.06	0.05	0.02	-0.08	-0.05	-0.06
202575*	5927	4.6	-0.03	-	-0.75	0.06	-	-	-0.06	-0.07	0.04	-	-	-0.04	0.02
203235	6071	4.1	0.05	2.57	-	-	0.02	-0.04	0.10	-0.04	0.11	0.06	-0.01	-0.01	-0.09
205702	6020	4.2	0.01	2.57	-	0.03	0.02	0.08	0.10	0.06	0.08	0.11	0.01	0.06	-0.04
206860	5787	4.6	-0.07	2.65	-	-	-	0.02	-0.08	0.01	0.02	0.06	-	-0.03	0.19
208038	4982	4.4	-0.08	-	0.85	-0.19	-	0.00	-0.04	-	0.05	0.01	-0.06	0.01	-0.12
208313	5055	4.3	-0.05	0.00	-	-0.02	-	0.13	0.10	-	0.20	0.04	0.02	0.04	-0.04
210667	5461	4.5	0.15	-	-	-0.31	0.06	0.00	-0.10	-0.01	0.06	0.01	-	0.07	-0.04
211472	5319	4.4	-0.04	-	-	-0.07	-0.10	-0.01	0.00	-0.12	0.05	0.00	-0.05	-0.01	-0.02
215704	5418	4.2	0.07	-	-	-	-	-	-	-0.03	-	-	-	-	-
216520	5119	4.4	-0.17	-	-0.30	0.20	-	0.10	0.09	-	0.01	0.02	-0.08	-0.07	-0.08
217014	5778	4.2	0.14	1.35	-	-	0.04	-0.06	0.06	-0.12	0.08	-0.06	0.00	0.09	0.06
217813*	5845	4.3	0.03	2.6	-	-0.3	-	-0.04	-0.01	-	0.04	-0.01	-0.09	0.09	-0.12
218868	5534	4.6	0.25	-	0	-0.37	-	0.08	-0.1	-	0.13	-0.04	-	0.06	-0.05
219134	4900	4.2	0.05	-	-	-	-	-	-	-	-	-	-	-	-
219538	5114	4.4	-0.09	-	0.00	0.09	-	0.12	0.03	-	0.09	0.06	0.02	-0.01	0.05
219623	5949	4.2	0.04	2.6	-	-	-	0.2	-0.05	-	0.11	0.07	-0.1	-0.07	0.00
220140	5144	4.6	-0.03	2.15	-	-	-	0.21	-0.18	-	0.03	0.16	-0.04	-0.02	-0.15
220182	5364	4.5	-0.03	1.80	-	0.03	-	-0.02	0.05	-	0.01	0.05	0	0.08	-0.11
220221	4868	4.5	0.16	-	-	-0.22	-	0.21	-0.08	-	0.12	0.05	0.04	0.02	0.20
221354	5242	4.1	-	-	-	-	-	-0.04	-	-	-	-	-	-	0.11
221851	5184	4.4	-0.09	-	0.00	0.07	-	0.07	0.1	-	0.02	0.07	-0.09	-0.04	-0.08
222143*	5781	4.3	0.09	1.93	-	-0.09	-	-0.06	-0.03	-	0.04	0.09	-0.08	0.05	-0.19
224465*	5745	4.5	0.08	-	-	-0.05	-	0.05	-0.05	-	0.24	0.04	-0.01	0.02	-0.09
BD+12 063	4859	4.4	-0.22	-	-	0.10	-	0.26	0.00	-	0.15	-0.02	-0.14	0.13	0.04

Table A3 (continued: Y–Eu)

HD	$T_{\text{eff}}(\text{K})$	$\log g$	[Fe/H]	[Y/Fe]	[Zr/Fe]	[Ba/Fe]	[La/Fe]	[Ce/Fe]	[Nd/Fe]	[Sm/Fe]	[Eu/Fe]
166	5514	4.6	0.16	-0.05	-0.15	0.12	-0.24	-0.12	0.00	-0.13	-0.09
1562	5828	4.0	-0.32	-0.02	-0.06	0.00	-0.02	0.07	0.08	0.07	–
1835	5790	4.5	0.13	0.02	-0.08	0.04	-0.22	0.01	-0.11	–	0.06
3651	5277	4.5	0.15	-0.12	-0.11	-0.14	-0.23	-0.12	-0.09	-0.18	-0.08
4256	5020	4.3	0.08	-0.15	-0.19	-0.16	-0.23	-0.04	-0.04	-0.03	–
4307	5889	4.0	-0.18	-0.07	-0.07	0.08	0.03	-0.04	0.05	0.06	0.12
4614	5965	4.4	-0.24	0.05	-0.02	0.02	-0.06	-0.05	0.07	0.06	0.08
5294	5779	4.1	-0.17	-0.04	-0.1	0.15	-0.15	0.02	-0.01	-0.09	0.01
7590	5962	4.4	-0.1	-0.1	-0.14	0.11	-0.11	-0.1	0.04	0.01	0.07
7924	5165	4.4	-0.22	0.00	0.03	-0.05	-0.01	0.10	0.12	0.06	0.04
8648	5790	4.2	0.12	-0.02	-0.07	-0.04	-0.19	-0.04	-0.13	-0.19	-0.13
9407	5666	4.45	0.05	-0.11	-0.1	-0.02	-0.23	-0.12	-0.06	-0.06	-0.03
9826	6074	4.0	0.10	-0.11	–	-0.02	-0.32	-0.08	–	-0.06	–
10086	5696	4.3	0.13	-0.18	-0.15	-0.06	-0.27	-0.17	-0.17	-0.18	-0.08
10307	5881	4.3	0.02	0.00	-0.09	-0.02	-0.19	-0.01	-0.13	-0.10	0.12
10476	5242	4.3	-0.05	-0.01	-0.07	0.00	-0.10	0.05	0.15	-0.1	-0.06
10780	5407	4.3	0.04	-0.01	0.06	0.09	-0.06	0.01	0.05	-0.08	0.05
11007	5980	4.0	-0.20	-0.11	0.07	0.05	-0.12	-0.07	0.05	0.03	0.19
12051	5458	4.55	–	–	–	–	–	–	–	–	–
12856	5766	4.5	-0.24	-0.11	-0.18	-0.04	-0.08	-0.01	0.05	0.11	0.16
13507	5714	4.5	-0.02	0.06	-0.09	0.11	-0.09	0.09	0.12	-0.09	0.16
14374	5449	4.3	-0.09	0.10	-0.06	0.02	-0.12	0.15	0.05	-0.02	0.13
17674	5909	4.0	-0.14	-0.14	-0.12	-0.03	-0.13	-0.07	-0.01	-0.06	-0.02
17925	5225	4.3	-0.04	0.01	-0.07	0.03	-0.16	0.13	0.08	-0.03	0.08
18632	5104	4.4	0.06	-0.13	-0.19	-0.04	-0.22	-0.13	-0.10	-0.09	-0.04
18803	5665	4.55	0.14	-0.16	-0.2	0.00	-0.29	-0.14	-0.13	-0.19	-0.02
19019	6063	4.0	-0.17	-0.02	0.03	0.17	-0.14	-0.04	0.07	-0.03	–
19373	5963	4.2	0.06	-0.07	-0.08	-0.03	-0.24	-0.05	-0.07	-0.10	0.03
20630	5709	4.5	0.08	-0.12	-0.18	0.07	-0.22	-0.09	-0.06	-0.17	–
22049	5084	4.4	-0.15	0.04	0.11	0.15	0.01	0.18	0.20	0.14	0.24
22484	6037	4.1	-0.03	-0.13	-0.1	0.03	-0.19	-0.02	-0.09	-0.09	0.02
22556	6155	4.2	-0.17	0.00	0.05	0.04	-0.07	0.05	0.17	-0.01	0.21
24053	5723	4.4	0.04	0.07	-0.08	0.11	-0.11	0.03	0.09	0.08	0.10
24206	5633	4.5	-0.08	–	–	–	–	–	–	–	–
24496	5536	4.3	-0.13	-0.10	-0.19	-0.12	-0.14	-0.02	-0.01	-0.07	0.10
25665	4967	4.7	0.01	-0.17	-0.11	-0.03	-0.20	-0.05	-0.12	-0.15	0.06
25680	5843	4.5	0.05	-0.07	-0.20	0.05	-0.16	-0.11	-0.04	-0.03	0.02
26923	5920	4.4	-0.03	-0.05	-0.04	0.28	-0.11	-0.12	-0.01	-0.01	0.00
28005	5980	4.2	0.23	0.07	-0.08	0.00	-0.27	-0.03	-0.06	-0.14	-0.13
28447	5639	4.0	-0.09	0.03	-0.12	0.03	-0.15	-0.02	0.06	0.02	0.13
29150	5733	4.3	0.00	0.06	-0.10	-0.03	-0.12	-0.03	0.00	-0.01	0.04
29310	5852	4.2	0.08	-0.06	-0.13	0.02	–	-0.09	-0.17	–	–
29645	6009	4.0	0.14	-0.12	-0.09	-0.07	-0.31	-0.11	-0.17	-0.18	-0.1
30495	5820	4.4	-0.05	0.11	0.10	0.19	-0.14	0.07	0.14	0.18	0.07
33632	6072	4.3	-0.24	0.09	0.07	0.18	0.10	0.15	0.16	0.16	0.18
34411	5890	4.2	0.1	-0.14	-0.06	-0.06	-0.30	-0.08	-0.17	-0.09	–
37394	5296	4.5	0.09	-0.11	-0.2	0.06	-0.25	-0.11	-0.07	-0.15	-0.02
39587	5955	4.3	-0.03	-0.1	-0.01	0.14	-0.14	-0.04	-0.03	0.00	-0.03
40616	5881	4.0	-0.22	-0.06	0.04	0.12	-0.07	-0.01	0.11	0.13	-0.04
41330	5904	4.1	-0.18	-0.18	0.01	0.01	-0.08	-0.07	0.01	-0.06	0.22
41593	5312	4.3	-0.04	0.04	0.01	0.10	-0.08	-0.01	0.10	-0.14	-0.07
42618	5787	4.5	-0.07	-0.11	-0.18	0.02	-0.12	-0.08	-0.02	-0.01	0.09
42807	5719	4.4	-0.03	-0.09	-0.09	0.11	-0.12	-0.07	-0.01	-0.08	0.05
43587	5927	4.1	-0.11	-0.12	0.00	-0.04	-0.11	-0.06	-0.05	-0.09	0.15
43856	6143	4.1	-0.19	-0.03	-0.08	0.15	-0.03	-0.03	0.03	0.14	0.18
43947	6001	4.3	-0.24	0.00	0.02	0.06	0.00	-0.02	0.16	0.07	0.20
45067	6058	4.0	-0.02	–	–	–	–	–	–	–	–
45088	4959	4.3	-0.21	-0.06	-0.19	0.04	-0.16	-0.07	0.06	-0.03	0.13
48682	5989	4.1	0.05	-0.17	-0.17	-0.08	-0.28	-0.16	-0.18	-0.15	-0.08
50692	5911	4.5	-0.1	-0.08	-0.18	0.03	-0.09	-0.08	-0.01	0.11	0.22
51419	5746	4.1	-0.37	-0.05	-0.03	-0.08	-0.1	-0.01	0.07	0.01	0.26
51866	4934	4.4	0.00	-0.14	-0.17	-0.07	-0.23	-0.11	-0.10	-0.13	0.02
53927	4860	4.65	-0.22	-0.14	-0.13	-0.02	-0.10	-0.09	-0.03	-0.12	0.19

Table A3 (continued)

HD	$T_{\text{eff}}(\text{K})$	$\log g$	[Fe/H]	[Y/Fe]	[Zr/Fe]	[Ba/Fe]	[La/Fe]	[Ce/Fe]	[Nd/Fe]	[Sm/Fe]	[Eu/Fe]
54371	5670	4.2	0.06	-0.17	-0.18	-0.01	-0.23	-0.16	-0.13	-0.15	0.03
55575	5949	4.3	-0.31	-0.07	0.04	0.02	0.06	-0.07	0.14	0.13	0.20
58595	5707	4.3	-0.31	0.07	0.02	0.01	0.03	0.18	0.15	0.15	0.20
59747	5126	4.4	-0.04	-0.08	-0.14	0.09	-0.15	0.04	0.04	-0.08	0.02
61606	4956	4.4	-0.12	0.00	—	0.02	0.03	0.19	0.15	0.20	0.13
62613	5541	4.4	-0.1	0.02	0.01	0.00	-0.07	0.02	0.05	0.08	-0.06
63433	5693	4.35	-0.06	-0.16	-0.18	0.02	-0.16	-0.09	-0.02	-0.07	0.03
64468	5014	4.2	0.00	-0.19	-0.12	-0.17	-0.25	-0.17	-0.08	-0.13	—
64815	5864	4.0	-0.33	0.07	0.07	0.07	0.01	0.03	0.17	0.24	—
65874	5936	4.0	0.05	0.00	-0.09	-0.07	-0.16	0.01	-0.10	-0.11	-0.11
68638	5430	4.4	-0.24	0.07	0.02	0.05	0.15	0.18	0.10	0.12	0.08
70923	5986	4.2	0.06	-0.07	-0.09	-0.06	-0.04	-0.08	-0.13	-0.07	-0.12
71148	5850	4.2	0.00	-0.02	-0.08	-0.01	-0.03	0.03	-0.01	-0.06	-0.06
72760	5349	4.1	0.01	-0.04	-0.01	0.04	-0.05	0.00	-0.02	-0.04	0.05
72905	5884	4.4	-0.07	0.03	-0.05	0.11	-0.03	0.01	-0.01	0.04	0.01
73344	6060	4.1	0.08	-0.08	-0.15	-0.02	-0.07	-0.15	-0.16	-0.09	-0.04
75732	5373	4.3	0.25	-0.20	0	-0.13	-0.15	-0.01	-0.07	0.04	-0.11
75767	5823	4.2	-0.01	-0.13	-0.14	0.04	-0.21	-0.16	-0.1	-0.09	—
76151	5776	4.4	0.05	-0.01	-0.07	-0.03	0.02	-0.03	-0.04	-0.12	-0.06
81809	5782	4.0	-0.28	—	—	—	—	—	—	—	—
82443	5334	4.4	-0.03	-0.13	-0.20	0.13	-0.12	-0.12	-0.05	-0.08	0.12
87883	5015	4.4	0.00	-0.05	-0.15	-0.05	-0.08	-0.01	0.08	-0.05	0.02
88072	5778	4.3	0	0.01	0.06	-0.03	0.00	-0.01	0.17	-0.06	0.15
89251	5886	4.0	-0.12	0.09	-0.09	0.05	0.12	-0.01	0.02	0.11	0.16
89269	5674	4.4	-0.23	0.07	0.08	0.03	0.06	0.10	0.23	0.12	0.20
94765	5077	4.4	-0.01	-0.02	-0.09	0.07	-0.11	0.01	0.06	-0.04	—
95128	5887	4.3	0.01	-0.04	0.00	-0.05	-0.04	-0.01	0.05	-0.05	—
97334	5869	4.4	0.06	-0.12	-0.17	0.13	-0.19	-0.16	-0.13	-0.13	-0.01
97658	5136	4.5	-0.32	-0.12	0.01	-0.03	-0.09	-0.04	0.06	0.05	0.19
98630	6060	4.0	0.22	0.02	-0.18	-0.18	-0.24	-0.05	-0.08	-0.18	-0.10
101177	5932	4.1	-0.16	0.02	0.00	0.01	-0.05	0.01	0.06	0.04	0.15
102870	6055	4.0	0.13	-0.07	-0.04	-0.03	-0.23	-0.06	-0.13	-0.15	-0.09
105631	5416	4.4	0.16	-0.18	-0.19	-0.02	-0.21	-0.19	-0.16	-0.18	-0.04
107705	6040	4.2	0.06	-0.05	-0.13	0.06	—	0.05	-0.13	-0.03	-0.05
108954	6037	4.4	-0.12	0.05	0.02	0.11	0.01	0.02	0.10	-0.03	0.06
109358	5897	4.2	-0.18	-0.04	0.06	-0.05	-0.07	-0.05	-0.04	0.00	0.04
110463	4950	4.5	-0.05	0.05	-0.03	0.04	-0.08	0.05	0.16	0.00	0.09
110833	5075	4.3	0.00	0.00	0.02	-0.04	-0.1	0.02	0.09	-0.07	—
111395	5648	4.6	0.10	-0.04	-0.03	0.19	-0.2	0.04	0.07	0.00	0.02
114710	5954	4.3	0.07	-0.01	-0.06	0.11	0.02	0.05	0.00	-0.01	-0.03
115383	6012	4.3	0.11	0.00	-0.08	0.12	-0.12	-0.05	-0.10	-0.01	0.05
116956	5386	4.55	0.08	-0.08	-0.17	0.05	-0.18	-0.03	-0.02	-0.11	0.04
117043	5610	4.5	0.21	0.03	-0.04	0.10	-0.09	0.01	-0.10	-0.01	-0.07
119332	5246	4.45	-0.07	-0.14	-0.08	-0.07	-0.16	-0.01	0.04	0.03	0.07
122064	4937	4.5	0.07	-0.19	—	-0.07	0.02	0.16	—	0.15	0.07
125184	5695	4.3	0.31	0.03	-0.07	0.04	-0.23	0.07	-0.01	-0.05	-0.07
126053	5728	4.2	-0.32	0.03	0.04	-0.13	0.12	-0.06	0.09	0.20	0.06
128311	4960	4.4	0.03	-0.07	0.00	-0.03	-0.17	-0.04	0.02	-0.08	0.04
130307	4990	4.3	-0.25	-0.05	-0.04	0.08	-0.02	0.04	0.21	0.04	0.20
130948	5943	4.4	-0.05	-0.06	-0.19	0.15	-0.15	-0.12	0.00	-0.14	0.07
135204	5413	4.0	-0.16	—	—	—	—	—	—	—	—
135599	5257	4.3	-0.12	0.00	0.08	0.10	0.02	0.06	0.11	0.03	0.11
137107	6037	4.3	0.00	-0.02	0.00	0.09	-0.05	0.04	-0.05	-0.18	—
139341	5242	4.6	0.21	—	—	—	—	—	—	—	—
139777	5771	4.4	0.01	-0.14	-0.11	0.14	-0.25	-0.12	-0.05	-0.1	-0.09
139813	5408	4.5	0.00	-0.10	-0.20	0.15	-0.17	0.04	-0.03	0.04	0.12
140538	5675	4.5	0.02	-0.02	0.11	0.06	-0.01	0.1	0.01	0.01	0.12
141004	5884	4.1	-0.02	-0.12	-0.11	0.00	-0.20	-0.06	-0.09	-0.11	0.11
141272	5311	4.4	-0.06	-0.18	-0.06	0.14	-0.14	-0.04	0.02	-0.03	0.08
142267	5856	4.5	-0.37	-0.12	-0.04	-0.03	0.07	-0.01	0.11	0.24	0.19
144287	5414	4.5	-0.15	0.05	-0.06	-0.03	0.15	0.10	0.13	0.05	—
145675	5406	4.5	0.32	-0.05	-0.10	-0.09	-0.16	0.03	0	-0.07	-0.03

Table A3 (continued)

HD	$T_{\text{eff}}(\text{K})$	$\log g$	[Fe/H]	[Y/Fe]	[Zr/Fe]	[Ba/Fe]	[La/Fe]	[Ce/Fe]	[Nd/Fe]	[Sm/Fe]	[Eu/Fe]
146233	5799	4.4	0.01	-0.02	-0.05	0.01	-0.01	-0.02	-0.01	-0.08	0.08
149661	5294	4.5	-0.04	-0.07	0.05	0.01	0.06	0.08	0.02	-0.09	0.03
149806	5352	4.55	0.25	-0.18	-0.18	0.05	-0.27	-0.08	-0.11	-0.16	-0.08
151541	5368	4.2	-0.22	-0.14	0.02	-0.15	0.01	0.04	0.06	-0.07	0.26
152391	5495	4.3	-0.08	—	—	—	—	—	—	—	—
154931	5910	4.0	-0.1	—	—	—	—	—	—	—	—
155712	4932	4.6	-0.06	-0.11	-0.14	-0.12	-0.17	-0.04	0	-0.05	-0.04
156668	4850	4.2	-0.07	-0.12	-0.09	-0.13	-0.15	-0.07	0.05	-0.02	0.05
159222	5834	4.3	0.06	—	—	—	—	—	—	—	—
159909	5749	4.1	0.06	—	—	—	—	—	—	—	—
160346	4983	4.3	-0.10	-0.06	—	-0.08	-0.03	0.06	0.14	-0.1	0.04
161098	5617	4.3	-0.27	-0.05	-0.04	0.11	0.02	0.00	0.13	0.05	0.26
164922	5392	4.3	0.04	-0.15	0.04	-0.10	—	0.08	0.03	0.01	0.10
164922	5392	4.3	0.04	—	—	—	—	—	—	—	—
165173	5505	4.3	-0.05	-0.13	—	-0.07	—	0.09	0.07	0.13	0.09
165341	5314	4.3	-0.08	-0.21	0.04	0.03	-0.04	0.12	0.17	0.15	—
165476	5845	4.1	-0.06	-0.07	-0.07	-0.06	-0.10	-0.10	0.00	-0.09	—
165670	6178	4.0	-0.1	-0.06	—	0.10	0.06	-0.06	-0.08	0.15	—
166620	5035	4.0	-0.22	-0.14	—	-0.09	0.07	0.02	0	-0.03	0.16
168009	5826	4.1	-0.01	—	—	—	—	—	—	—	—
173701	5423	4.4	0.18	—	—	—	—	—	—	—	—
175742	5030	4.5	-0.03	-0.20	-0.14	0.06	-0.16	-0.13	-0.08	-0.09	0.05
176377	5901	4.4	-0.17	-0.17	-0.15	0.05	-0.13	-0.09	0.02	0.07	0.14
176841	5841	4.3	0.23	-0.16	-0.10	-0.12	-0.32	-0.09	-0.17	-0.08	-0.09
178428	5695	4.4	0.14	-0.18	-0.19	0.04	-0.25	-0.15	-0.11	-0.16	0.03
180161	5473	4.5	0.18	-0.18	-0.14	0.07	-0.27	-0.15	-0.12	-0.09	-0.01
180161	5473	4.5	0.18	-0.18	-0.14	0.07	-0.27	-0.15	-0.12	-0.09	-0.01
182488	5435	4.4	0.07	-0.04	0.03	-0.07	—	0.03	0.07	—	-0.03
183341	5911	4.3	-0.01	0.04	-0.08	-0.08	-0.18	0.03	-0.07	-0.14	0.1
184385	5619	4.0	0.12	-0.18	-0.14	0.07	-0.25	-0.14	-0.15	-0.18	-0.02
184768	5713	4.2	-0.07	—	—	—	—	—	—	—	—
185144	5271	4.2	-0.33	-0.10	—	-0.02	-0.02	-0.02	0.1	-0.04	0.17
185414	5818	4.3	-0.04	-0.15	-0.09	0.07	-0.15	-0.10	-0.04	-0.08	0.04
186104	5753	4.2	0.05	—	—	—	—	—	—	—	—
186408	5803	4.2	0.09	-0.11	-0.11	-0.03	-0.08	-0.01	-0.04	-0.07	-0.05
187897	5887	4.3	0.08	-0.03	-0.05	0.03	-0.08	-0.10	-0.07	0.04	—
189087	5341	4.4	-0.12	0.08	0.07	0.1	0.09	0.14	0.17	0.06	0.06
190007	5076	4.4	0.16	-0.06	-0.19	-0.03	-0.26	-0.20	-0.16	-0.15	-0.04
190406	5401	4.4	0.05	-0.16	-0.15	0.045	-0.19	-0.14	-0.09	-0.11	-0.03
190470	5905	4.3	0.11	-0.16	-0.15	-0.08	-0.19	-0.07	-0.07	-0.11	0.01
190771	5130	4.3	0.13	-0.20	-0.2	-0.07	-0.29	-0.19	-0.19	-0.17	-0.06
191533	6167	3.8	-0.10	0.01	-0.11	0.09	-0.24	0.14	-0.06	-0.09	-0.06
191785	5766	4.3	-0.12	-0.12	-0.10	-0.24	-0.16	-0.11	-0.02	-0.07	0.14
195005	6075	4.2	-0.06	-0.09	-0.10	0.06	-0.14	-0.02	-0.12	-0.11	—
195104	6103	4.3	-0.19	0.10	-0.11	0.20	0.08	0.1	0.23	0.16	0.03
197076	5821	4.3	-0.17	0.11	0.12	0.08	0.10	0.08	0.21	0.13	0.21
199960	5878	4.2	0.23	-0.14	-0.12	-0.11	-0.33	-0.04	-0.17	-0.07	—
200560	5205	4.2	0.06	-0.03	-0.03	0.04	-0.18	-0.09	-0.04	-0.12	-0.09
202108	5712	4.2	-0.21	-0.04	-0.11	0.10	-0.13	-0.02	0.09	-0.09	0.15
202575	5927	4.6	-0.03	0.05	-0.04	0.09	-0.12	0.02	0.08	-0.02	0.10
203235	6071	4.1	0.05	-0.14	-0.12	-0.16	-0.12	-0.07	-0.09	-0.11	—
205702	6020	4.2	0.01	0.11	-0.10	-0.03	-0.15	-0.02	-0.04	—	-0.02
206860	5787	4.6	-0.07	-0.12	-0.17	0.05	-0.11	-0.04	0.02	0.05	—
208038	4982	4.4	-0.08	-0.08	-0.07	0.09	-0.10	-0.06	0.04	-0.04	0.1
208313	5055	4.3	-0.05	-0.11	-0.17	-0.09	-0.16	-0.06	0	-0.17	-0.03
210667	5461	4.5	0.15	-0.07	0.02	-0.04	-0.14	-0.01	-0.1	-0.12	-0.01
211472	5319	4.4	-0.04	0.05	-0.05	0.10	0.01	0.05	0.06	-0.07	—
215704	5418	4.2	0.07	—	—	—	—	—	—	—	—
216520	5119	4.4	-0.17	-0.13	0.00	-0.20	-0.12	0.00	0.07	0.08	0.09
217014	5778	4.2	0.14	-0.16	-0.09	-0.10	-0.29	-0.03	-0.13	-0.13	-0.05
217813	5845	4.3	0.03	-0.18	-0.17	0.04	-0.21	-0.12	-0.10	-0.14	-0.01
218868	5534	4.6	0.25	-0.10	-0.14	0.03	-0.24	-0.1	-0.10	-0.15	-0.03
219134	4900	4.2	0.05	—	—	—	—	—	—	—	—

Table A3 (continued)

HD	$T_{\text{eff}}(\text{K})$	$\log g$	[Fe/H]	[Y/Fe]	[Zr/Fe]	[Ba/Fe]	[La/Fe]	[Ce/Fe]	[Nd/Fe]	[Sm/Fe]	[Eu/Fe]
219538	5114	4.4	-0.09	-0.04	-0.05	-0.06	0.00	0.04	0.11	0.01	0.06
219623	5949	4.2	0.04	-0.17	-0.19	0.01	-0.28	-0.2	-0.18	-0.17	0.13
220140	5144	4.6	-0.03	-0.15	-0.11	0.05	-0.08	-0.16	-0.09	-0.12	0.00
220182	5364	4.5	-0.03	-0.06	-0.20	0.07	-0.18	-0.03	0.04	-0.06	0.10
220221	4868	4.5	0.16	-0.02	-0.06	0.02	-0.18	-0.06	-0.06	-0.04	-0.09
221354	5242	4.1	—	—	—	—	—	—	—	—	—
221851	5184	4.4	-0.09	-0.07	-0.13	0.02	-0.13	0.01	0.05	-0.07	0.11
222143	5781	4.3	0.09	-0.14	-0.14	0.09	-0.23	-0.15	-0.15	-0.17	-0.02
224465	5745	4.5	0.08	-0.18	-0.12	0.05	-0.19	-0.13	-0.13	-0.19	0.04
BD+12 063	4859	4.4	-0.22	0.00	-0.02	-0.18	-0.09	-0.03	-0.01	-0.02	0.05